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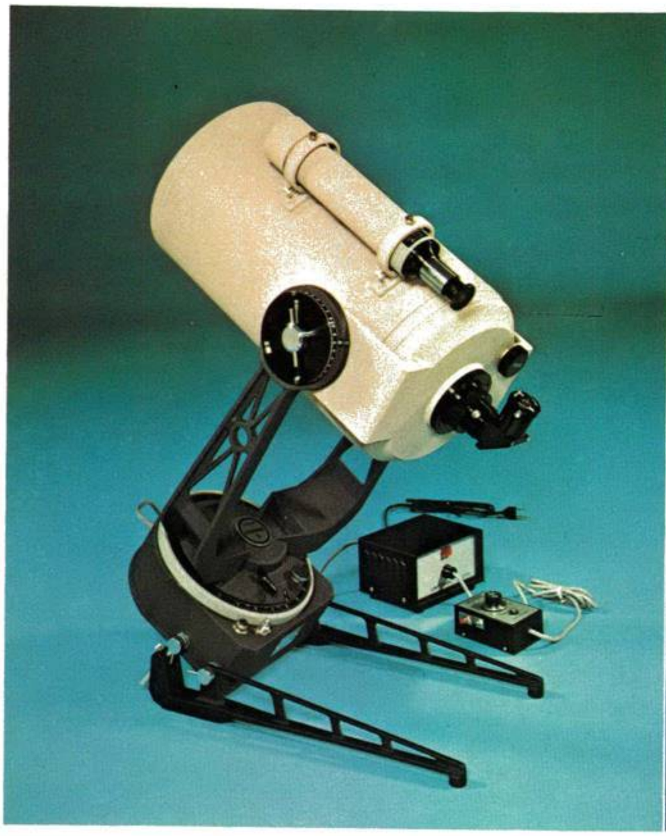

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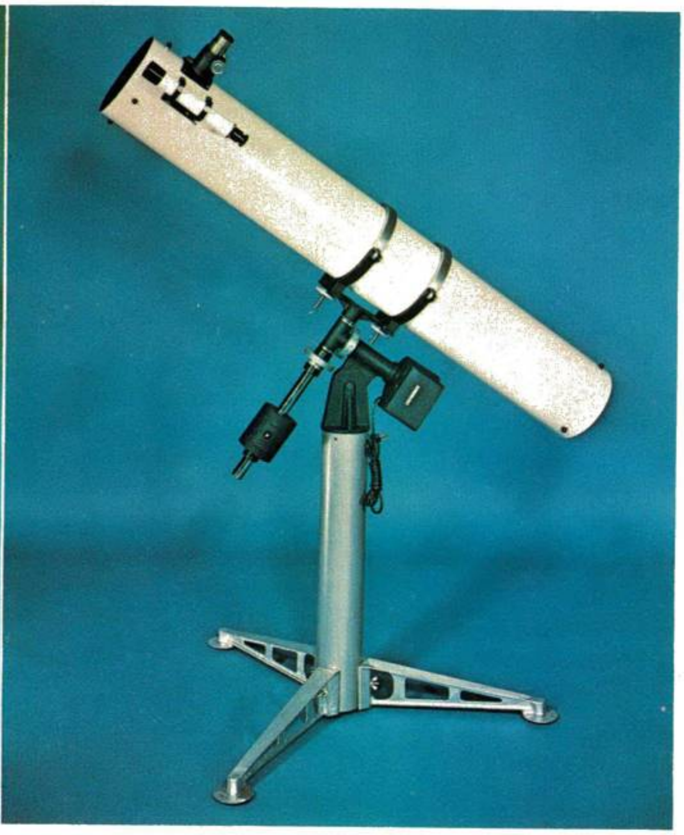

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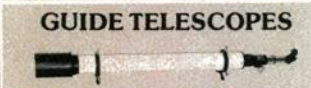

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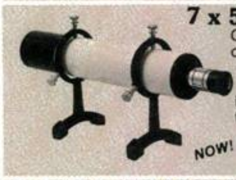

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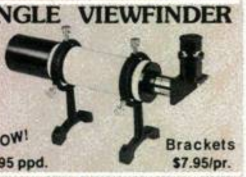

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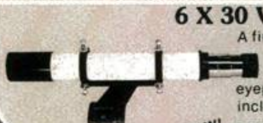

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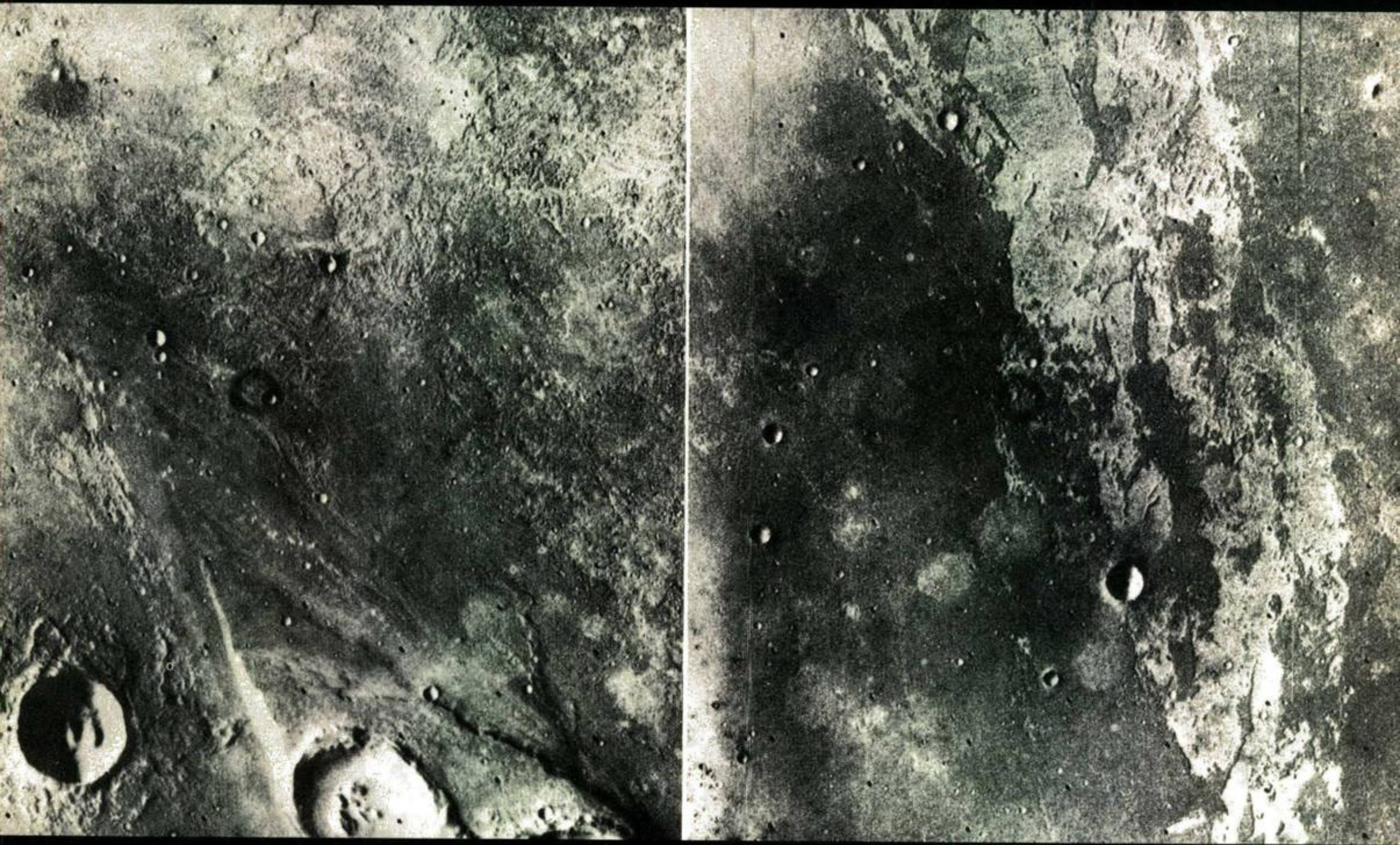
Chryse Site Looks Rough



by William K. Hartmann

Instead of the featureless, smooth, dusty plain that had been hoped for, the Viking orbiter pictures of Chryse revealed myriad different geologic structures. Although large impact craters were lacking in the area, clusters of small, 100-yard pits were common in some localities. These were apparently formed by ejecta blasted out of some large craters. Other high rimmed craters and conical hills may have been volcanic in origin. Large streamlined hills, 20 to 30 miles long, were probably formed by water flow or etched by windblown dust; they showed cliffs indicating erosion. Nearby, some regions showed incredibly intricate complexes of gullies about 100 yards across; landing in such an area might be fatal to Viking. Another landform, possibly related, was a light-floored complex of shallow channels several miles wide and bounded by bluffs, suggesting dangerous slopes. Floors of such channels might be smoother, perhaps covered by light dust.

One problem in site selection was that the Viking lander could be targeted with 99 percent certainty only in an elliptical area about 31 by 75 miles. It is difficult to find such a large area in Chryse totally devoid of ominous topography.

From June 22 through 26, photos were received showing still more details in the Chryse site. It became clear that many kinds of geologic processing had occurred in the area since the channels deposited their sediments. Geologists could recognize some stratigraphic units of known source, such as crater ejecta, and other units of unknown origin. At a meeting on June 25, all available information was considered by mission planners, who faced the decision of whether to target for the July 4 landing in Chryse. The consensus was that no one could predict whether 20 degree slopes and 10 inch boulders might exist in the region, since no one was sure of the geologic processes that had formed meter scale relief in the region.

The decision was announced on June 27 to delay the landing. The purpose was to allow more time to study the geology of other possible sites, such as the backup site at Tritonis Lacus, in a relatively "featureless" area east of Syrtis Major. Would small scale, secondary craters, gullies and bluffs dominate the small scale geography in all parts of Mars? Or can some smooth area, perhaps formed by deposition of sediments, be found? Late June and early July will be spent trying to answer these questions.

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Cover

A cloud of pumice emitted by an erupting volcano floats horizontally in the dense atmosphere of Venus, while far overhead, a perpetual rain of sulphuric acid turns the cloud cover a murky yellow color. A soil sampling probe rises from the deep trench in the foreground, preparing to link up with its mother ship. If life ever existed in Venus' past, fossil remains could be found only in rocks billions of years old — rocks that would be located at the bottom of just such a canyon. New methods of ensuring the survival of probes must be discovered before investigation into conditions on Venus reach the stage portrayed here. Artwork by Adolf Schaller.

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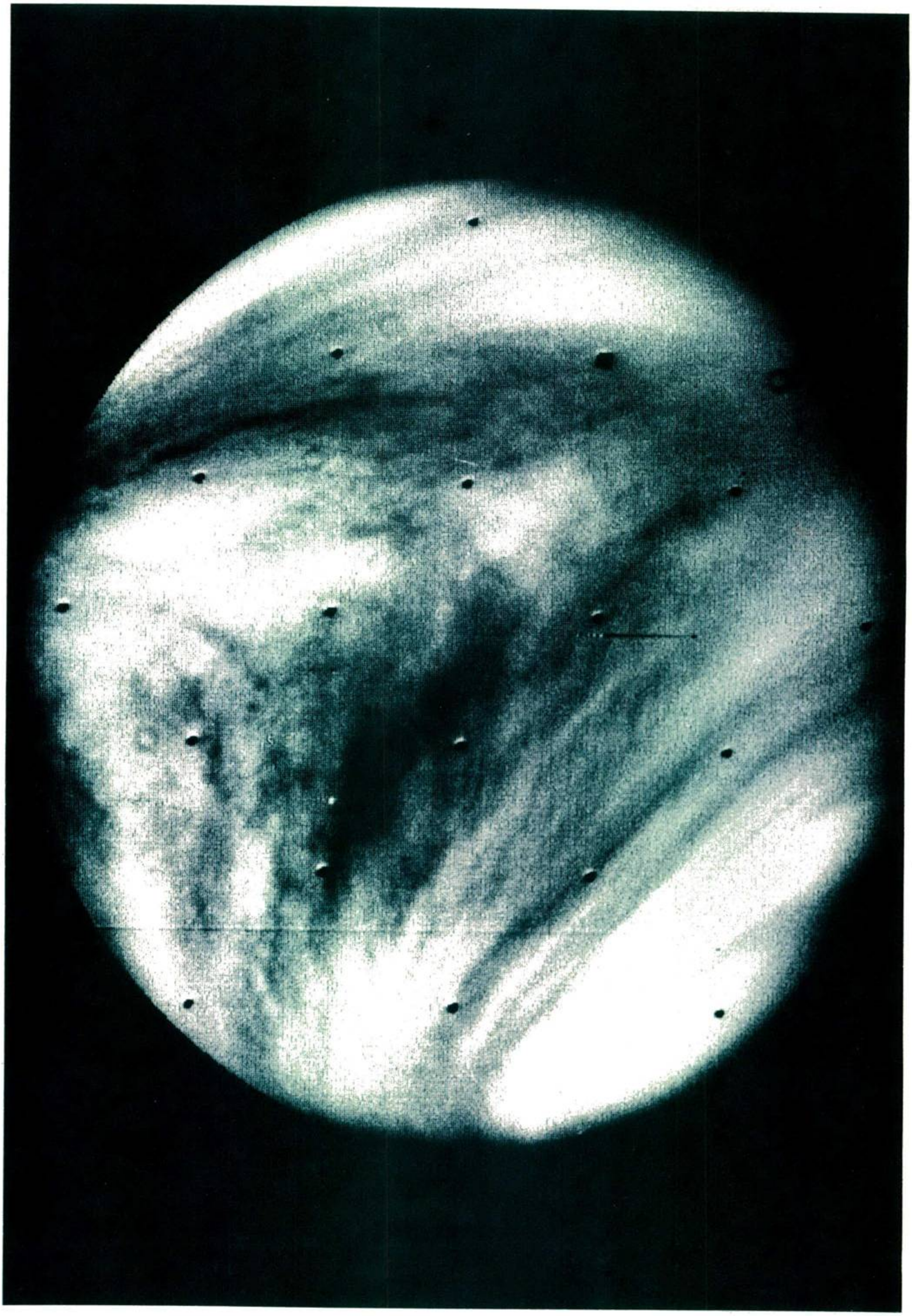
J. HERVAT 76

VENUS

by
James E. Oberg



Not too long ago, the planet Venus was thought of as "Earth's twin" in the sun's family. Venus was about the same size and density as Earth, received about the same amount of sunlight on its surface (although closer to the sun, it reflected more sunlight back into space), had a thick atmosphere, and in general appeared to be an inhabitable planet. Compared with desert Mars and stormy Jupiter, sunbaked Mercury and frozen Pluto, Venus seemed the most likely habitat for extraterrestrial life forms in the solar system. Images of lush jungles and steaming swamps had enormous appeal for astronomers and science fiction writers alike. But the ever-present clouds hid the truth from Earthbound observers over the centuries.

With the advent of modern astronomy and space probes, the planet Venus has finally yielded a few of its secrets. Many tantalizing mysteries remain regarding this brightest closest planet, but one overwhelming and undeniable fact now stands out: Far from being a world hospitable to life, Venus is a contemporary incarnation of medieval visions of Hell.

With scorching temperatures, a crushing, unbreathable atmosphere, and bizarre day-night cycles and optical effects, the planet Venus no longer beckons as a nice place to visit or settle. Instead, it has become a more interesting planet; it may even hold part of the solution to some of Earth's secrets.

On Earth, psychologists and sociologists can study the behavior of human identical twins raised separately under different circumstances, in an attempt to measure the effects of heredity and environment on human character development.

Planetary geologists face similar questions in regard to Earth and Venus. If the two planets began alike, with similar compositions, what events and environments caused their development to part over the 4-1/2 billion years since their formation? Why is Earth covered with water and teeming with life, while Venus stands sterile and hostile? If there are, in fact, millions of planets in the galaxy that had the same original composition as Earth and Venus, have these planets developed into millions of beckoning copies of Earth — or millions of forbidding copies of Venus?

Caption for pages 6 & 7

Having fulfilled its mission, the squat hulk of the Soviet probe Venus 9 sits inert in a desolate Venusian landscape; the scattering of light in the dense atmosphere produces its reddish color. Before its sensitive instruments succumbed to the rigors of 900 degree temperatures and an atmospheric pressure 90 times that of Earth, the probe returned photographs showing that the planet's surface was both rockier and more brightly lit by the sun than was thought possible. Artwork by James Hervat.

This photograph of Venus, obtained by Mariner 10 during its flyby in early February 1974, was taken through an ultraviolet filter and shows the general circulation patterns of Venus' upper atmosphere. The clouds appear to be rotating with extreme speed, but this is actually an optical illusion. NASA photograph.

Some essential differences must be understood, though the causes of the effects are still not known for certain. Earth has a magnetic field and continental drift, while Venus apparently does not. Why should this be so? What effects would these have on the evolution of the entire planet? Is there any connection with what can only be a freak accident — the possession by Earth of a large natural satellite? If this is related to planetary differences, it has profound implications for life on Earth, on Venus, and elsewhere in the universe.

After 15 years of spacecraft exploration and ground based studies, the old mysteries have been replaced by new ones. Today's astronomers are faced with more subtle enigmas than those encountered by previous generations.

To the ancients, Venus was the brightest star, the "mistress of the heavens". A puzzle even in those days, many observers did not realize that the morning star (Phosphorus) and the evening star (Hesperus) were really the same object.

With the invention of the telescope, the exploration of Venus began, with immediate, far-reaching effects for astronomical theories. Galileo's observation of Venusian phases proved that the planets shine with reflected light like the moon and Earth. The phases also disproved (by observation of both gibbous and crescent phases) a variant of the Ptolemaic theory that claimed that Venus only moved between Earth and the sun, and never behind the sun. Its orbit was found to be the most circular in the solar system, as well as the third most inclined to the ecliptic (after the eccentric paths of Mercury and Pluto). Its mass was measured by subtle gravitational effects on neighboring planets and passing asteroids. The existence of an atmosphere was confirmed by observations made during stellar occultations and solar transits.

Drawing analogies from Earth, astronomers assumed that the clouds on Venus, like those on Earth, were composed of water vapor. The chemistry that would allow modern scientists to guess at the violent Venusian atmospheric compounds was not developed until the 19th century.

Measurements of the planet's temperature, made early in the 20th century, produced low figures — below freezing in many cases. The reasonable assumption (and the correct one) was that this reading was off the tops of the cloud layers. The clouds were surprisingly and suggestively opaque to certain wavelengths of light.

Earthbound visions of Venus began to change radically in the 1950s, when measurements in the microwave frequencies (which could penetrate the atmosphere) gave an astonishing result. If all the microwave radiation from Venus was due to heat, the planet would have a surface temperature of more than 500 degrees Fahrenheit. Maintaining this steep temperature gradient between the surface and the upper atmosphere would require atmospheric pressures of 10 to 100 times as great as those on Earth.

The angular resolving power of Earth based microwave radiometers (instruments used to measure energy in one particular wavelength) could not determine where on Venus the microwave radiation was originating. Certain "nonthermal sources" were postulated for the higher-than-expected readings: lightning, ionospheric particles, radiation belts. To settle this question, scientists would have to measure microwaves in the center of the visible disk (looking straight down through the atmosphere) and at its edges (looking through a much longer pathway of atmosphere). The higher reading would pinpoint the origin of the microwaves — either thermal (on the surface) or nonthermal (in the atmosphere).

By the time astronomers had learned enough to ask these questions and envisage such an experiment, space engineers were able to build a machine to carry it out. In 1962, the first Mariner spacecraft were launched toward Venus, and planetary exploration became "on site" as well as "remote."

Mariner 2 carried a half dozen instruments which established conclusively that microwaves were coming from the surface and not from the atmosphere (the "limb darkening" effect was clearly observed). This meant that Venus was as hot or hotter than Earth based readings had suggested. Other experiments were also performed. Radio occultation measured the depths of the atmosphere by passing radio signals through it, while tracking of the bending of the probe's trajectory gave precise new values for the planet's mass. A magnetic field and radiation belts were sought, but not found.

Later American flyby probes in 1967 and 1974 studied the atmosphere and radiation environment more closely. Of particular interest was the Venusian ionosphere, which is pushed down against the upper atmosphere by the solar wind which is not warded off, as on Earth, by a powerful magnetic field. The transport of energy and matter across this boundary determines the cycle of planetary climate and the long term evolution of its atmosphere. But flyby probes could not be certain about atmospheric conditions, nor could they determine the nature of the surface.

While the United States was probing Venus from a range of a few thousand miles, avoiding the difficult problems of high speed entry and data return to Earth, the Soviet Union concentrated on dropping small instrumented capsules into the atmosphere. Direct measurements of temperature, pressure and deceleration could confirm and embellish the results achieved on Earth and in space.

The USSR launched two or three probes every 19 months for more than a decade, beginning in 1961. A total of 20 rockets were shot into space as part of the project. Initially plagued by equipment failures and insufficient designs, the persistent program ultimately led to the brilliant engineering successes and important scientific discoveries of the epochal Venus 9 and 10 landings in late 1975.

In 1967, after six years of failure, Venus 4 became the first spacecraft to enter a planet's atmosphere and send data back to Earth. Soviet designers, still skeptical of Mariner 2 data, had built a 900 pound probe to penetrate an atmosphere far thinner and cooler than what lay in wait. Descending too slowly by a large parachute, the probe was crushed and burned tens of miles above the surface.

The next set of probes had smaller parachutes to allow them to pass through the atmosphere more quickly, before the heat could build up and fry the radios. Venus 5 and Venus 6 did reach lower altitudes, but both were destroyed when the actual conditions were far worse than even the most pessimistic Russian engineers had foreseen.

Space engineers and scientists eventually concluded that high American estimates had, if anything, been too low. Adding several hundred pounds of insulation and structural strength to a new spacecraft, they sent two more such vehicles into space. One rocket went astray just beyond Earth's atmosphere, but the second was right on course. In late 1970, Venus 7 reached the surface of the planet, intact and functioning. Before failing only minutes later, it reported a pressure 90 times that of Earth's sea level and a temperature of 900 degrees Fahrenheit.

After the engineering problems of survival had been solved, another probe was launched to make more elaborate scientific readings. Landing on the day side of Venus in 1972, Venus 8 sent back data on the light levels and on the chemical and physical properties of the surface rock: It looked like granite rubble.

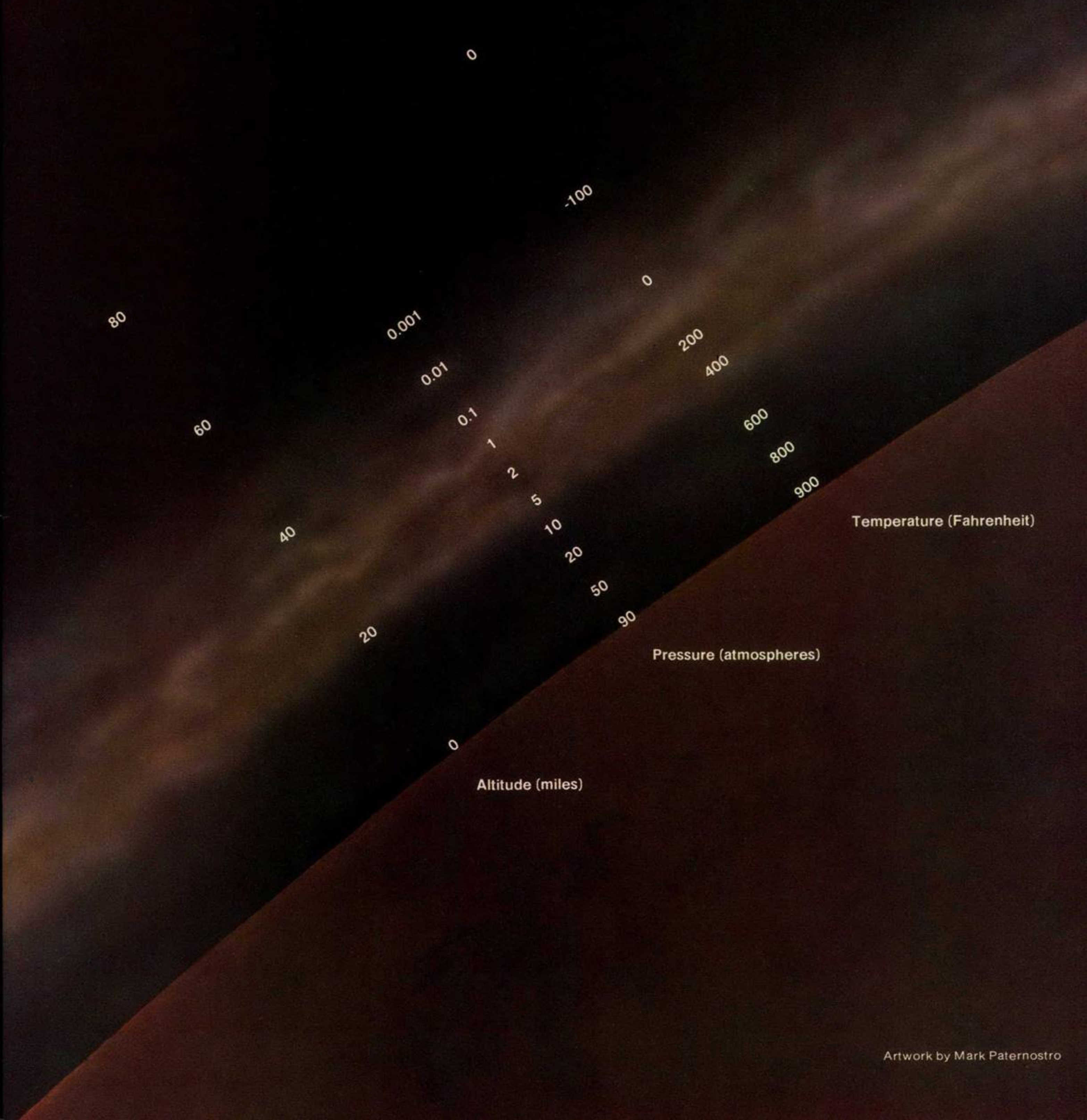
Three more years were spent in the design and testing of a new generation of unmanned space probes. (The main module had been flown on Mars missions since 1971, but the lander was of an entirely new design.) Weighing four times as much as the first generation of Soviet vehicles, the new spacecraft were comparable with the American Viking Mars probes in cost, booster size and instrumentation. In 1975, two Soviet probes of the new type were launched toward Venus.

As the ambitions of the Soviet space scientists had grown, so had their experience and capabilities. The Venus 9 and 10 probes each carried out an intricate space ballet and crucial series of successive descent stages. Both craft worked perfectly on the first try.

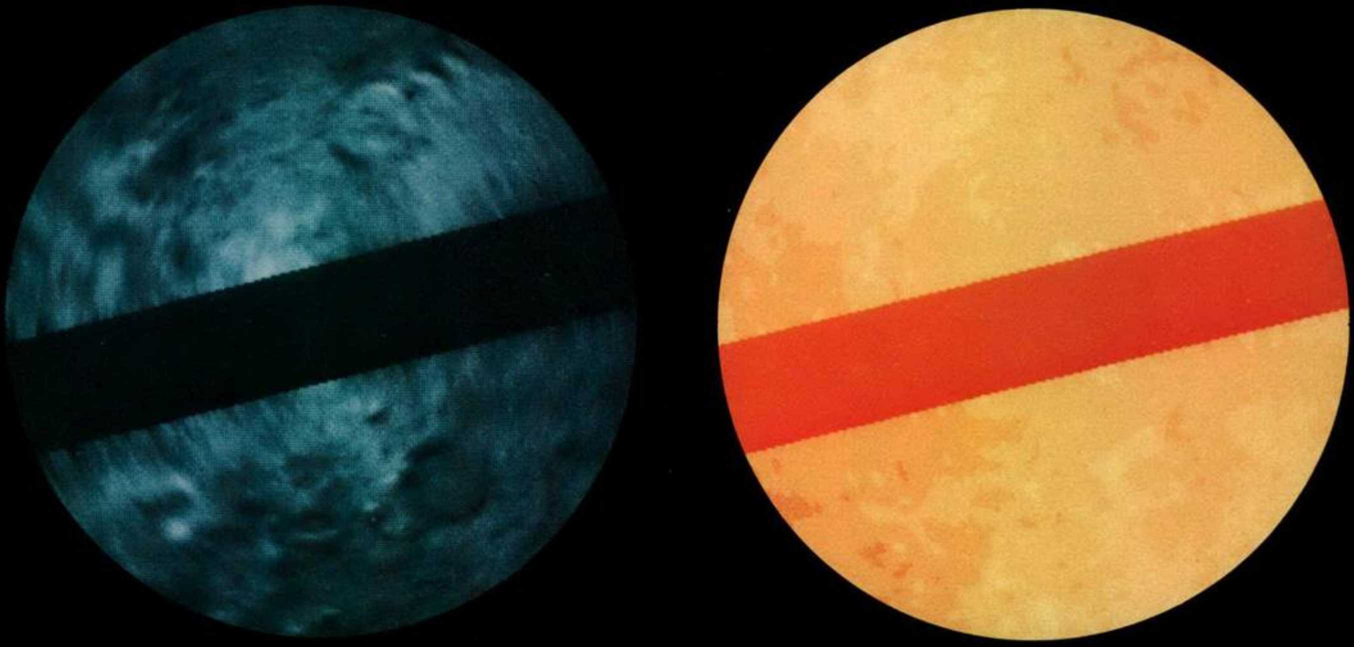
Several days out from Venus, each 3,400 pound lander capsule separated from the four ton mother craft by firing a small rocket motor. The two vehicles approached the planet at opposite edges — one to the west side and the other to the east. The lander was to whip around the left limb and hit the atmosphere near the subsolar point, while the orbiter passed the right limb at a higher altitude, missed hitting the atmosphere, and fired its main rocket engine to put it into orbit around the planet. Immediately afterward, it would fly directly over the descending lander probe and receive radio signals for several hours. The landing

The Atmosphere of Venus

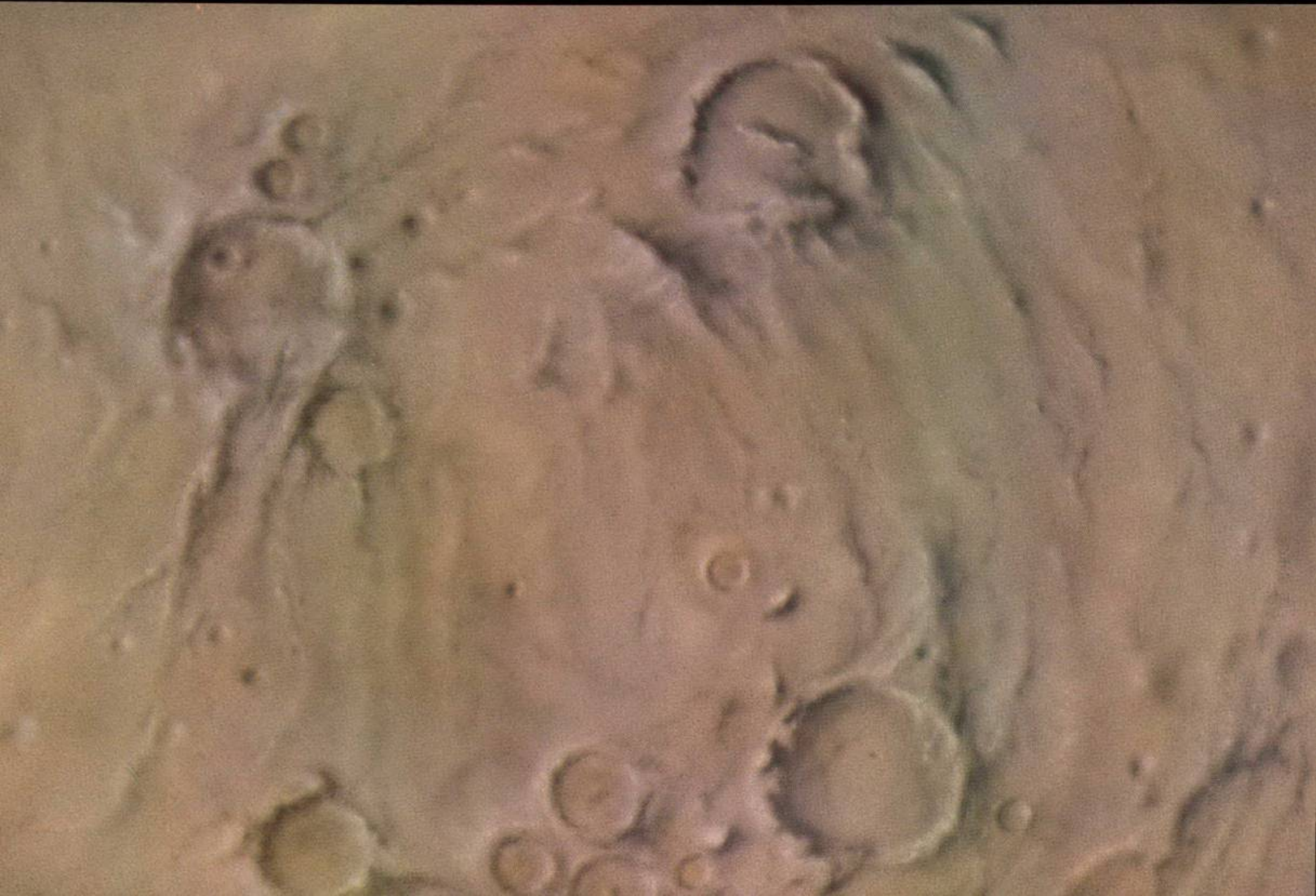
Venus' atmosphere has been probed by American and Russian spacecraft, theoretical calculation, and Earth based telescopes to yield the picture presented here. The dense clouds that obscure the surface do not reach to the ground, but end several tens of miles above it. The atmosphere above the clouds consists of simple molecules — mostly carbon monoxide — while inside the clouds more complex molecules, such as sulphuric acid, may have formed. Below the clouds in a region of increasing density, temperature and pressure, the major component of the atmosphere appears to be carbon dioxide.

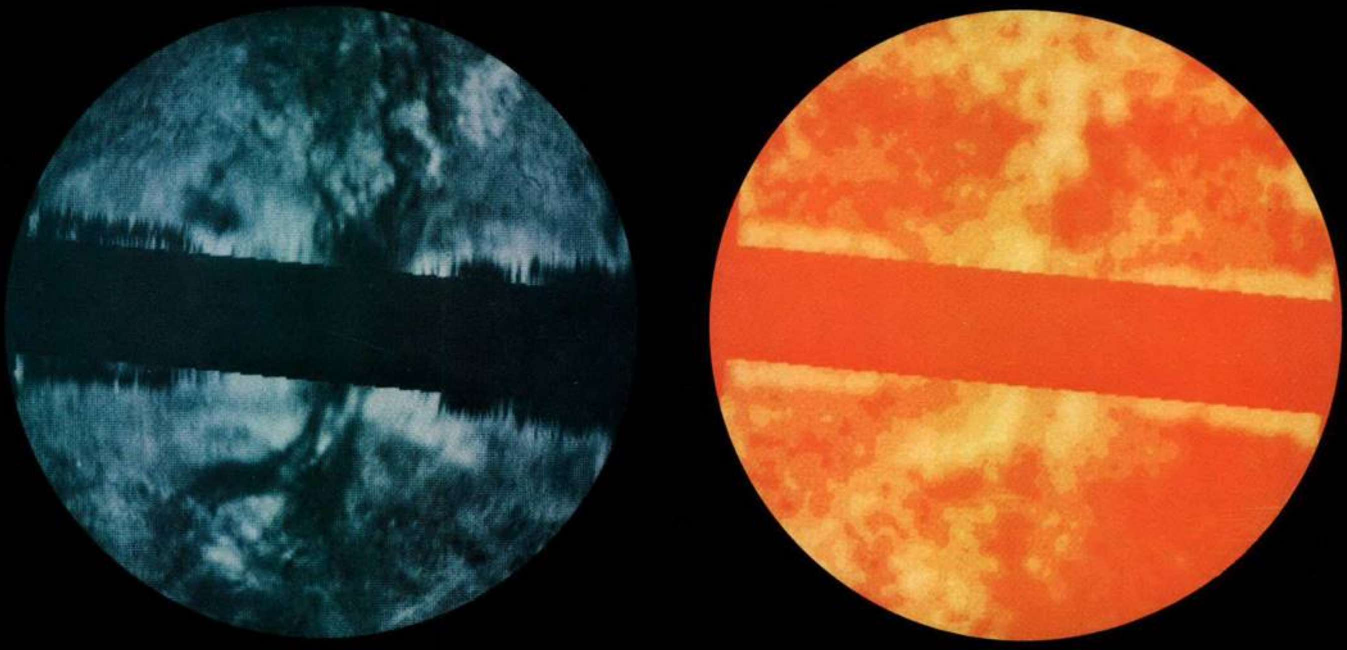

0
-100
0
200
400
600
800
900
Temperature (Fahrenheit)
0.001
0.01
0.1
1
2
5
10
20
50
90
Pressure (atmospheres)
80
60
40
20
0
Altitude (miles)

Artwork by Mark Paternostro

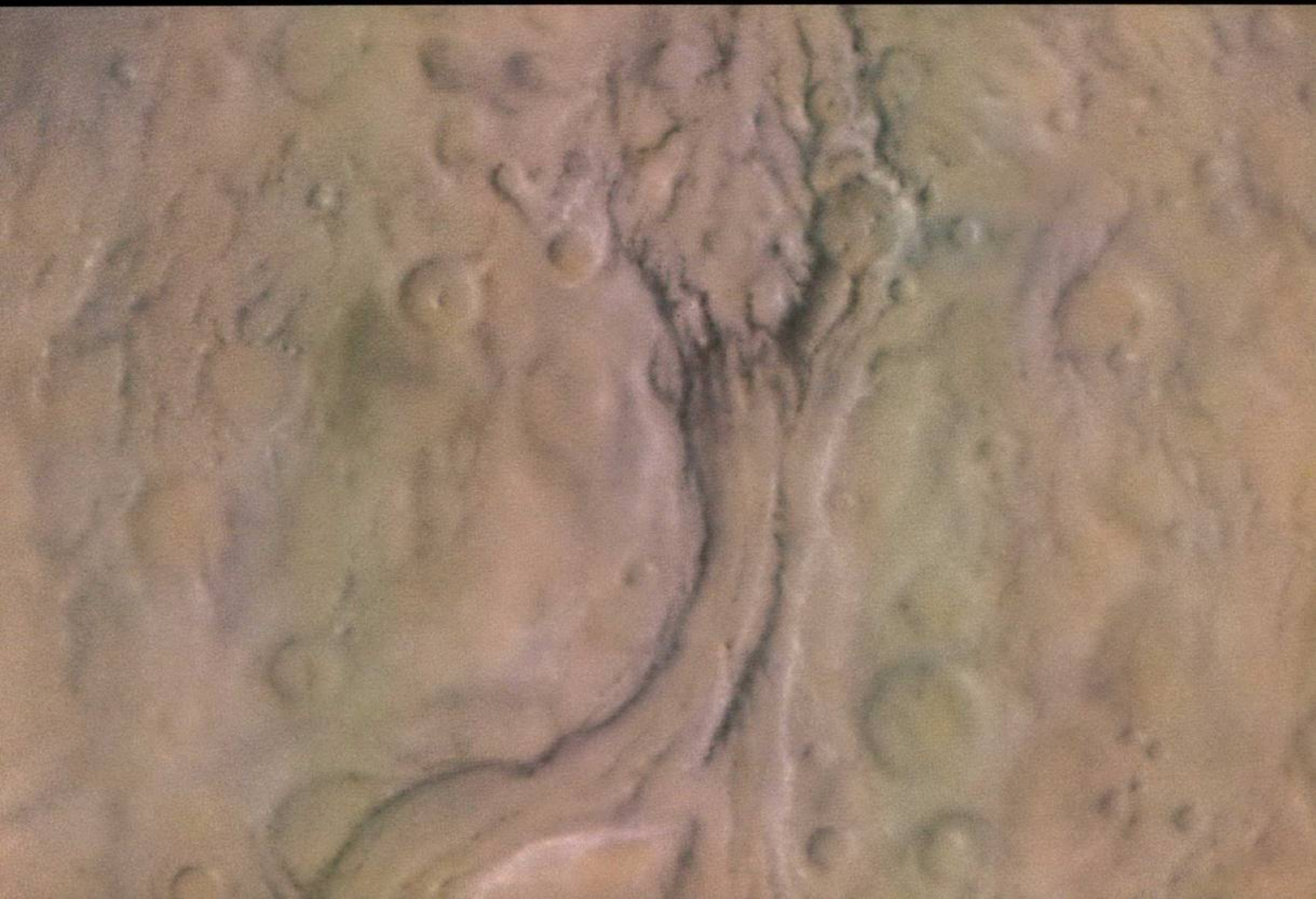


Craterlike shapes show on the round radar image (blue) of a 900 mile section of Venus' surface. Shown in shades of light and dark is the amount of radar power returned to Earth by the Venus surface. On the radar altimetry map (orange), shaded contours show a raised crater rim. The largest craters in the scene are about 100 miles in diameter, but only about 0.3 miles deep. Below is a rendition of the surface as it might appear if Venus' clouds allowed us to see it.

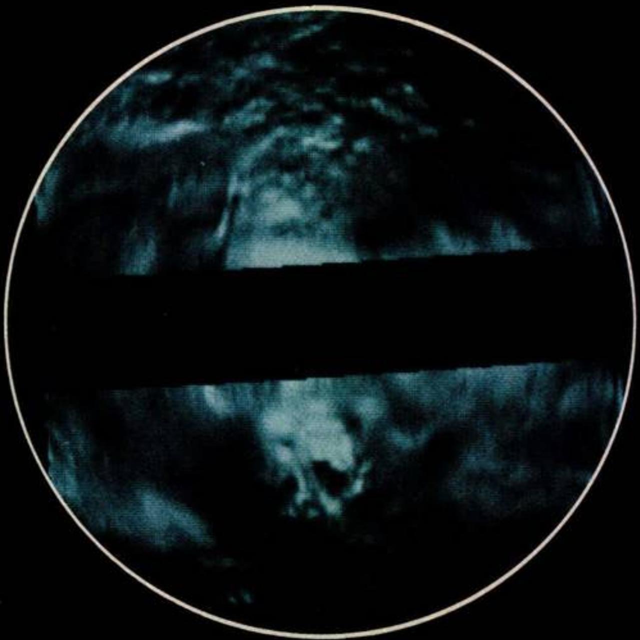




Venus appears to have a trough extending nearly the length of the radar image (900 miles) and measuring 75 miles wide. It is shallow — about one mile deep — and shows evidence of branching at the south (bottom) and possible "tributaries" at the northern end. The feature is interesting because it isn't really a groove, but rather a crack at the top of a bulge in the surface of the planet. Below: With the atmosphere removed, you might expect a trough as shown. Artwork by Victor Costanzo.

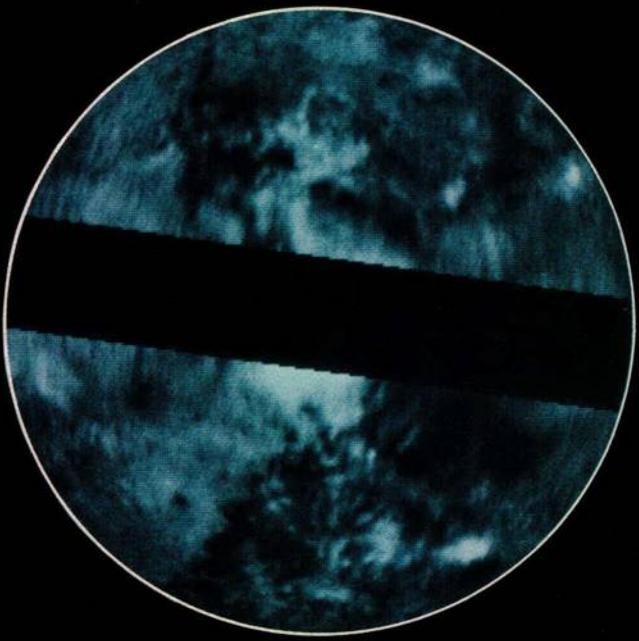


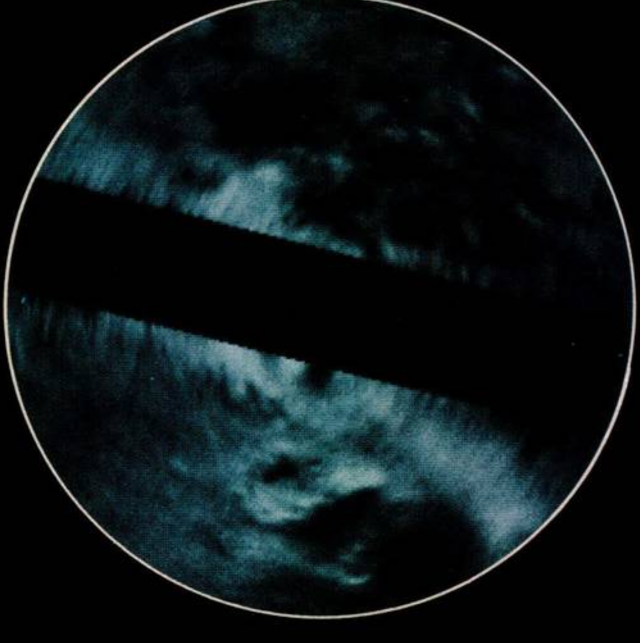
Venus radar images present a complex puzzle to the scientist attempting to understand the nature of the planet's surface. Familiarity with the geology of Earth, the moon, Mercury and Mars, as well as an understanding of how geologic processes may differ in different planetary environments, is necessary before a realistic interpretation of such images can be attempted. Further complicating interpretation is the number of radar artifacts, such as the dark lane up the middle of each image, blurring near the dark lane, and the strange appearance the radar image lends to the planetary surface detail. Dr. Michael Malin of the Jet Propulsion Laboratory has given the interpretations below. Radar imagery on this page and pages 12 and 13 are provided by Dr. Richard Goldstein, Jet Propulsion Laboratory.



Rough mountains appear in the upper quarter of this image, separated from a smooth plain by a nearly straight line indicating the possible presence of a fault. A linear feature located slightly left and above center, pointing north, may be another fault. At the approximate center of the lower half of the image lies what seems to be a cluster of mountains containing perhaps a dozen peaks in a region some 200 miles across. The individual peaks stand about one mile above the plain. This is suggestive of a region of volcanic activity.

In the complex and confusing imagery of this frame, several features can be deduced after careful analysis. The rough blotchy area in the right of the image is a plateau, raised about 6/10 of a mile above the bright area to the left. A thin, dark and light line appears to separate this region from areas to the left, and may be an escarpment (cliff). Altimetry data confirms that the ground is lower to the left of this feature. The bright spot in the lower right is the image of a mountainside that happened to be tipped directly toward Earth on the day this image was obtained. The average slope of the mountainside — about six degrees — can be determined from this reflection. Greater slopes may exist at higher resolution. Not very obvious is a feature located about halfway between the mountain and the image center — a canyonlike, winding feature appearing as a depression on the altimetry data. Very little more can be distinguished until higher resolution radar images can be obtained.





Prominent in this image is the large, round, craterlike feature in the lower half of the frame. Analysis of the image reveals it to be a summit caldera atop a volcanic pile some 350 miles across. Several lines of evidence favor the caldera interpretation: 1) it has a steep inner slope and a shallow outer slope; 2) it has multiple scarps only along one side (impact craters tend to be symmetrical); 3) the large protruding ridge to the right is typical of volcanic features, and 4) the ratio of its interior and exterior diameters is typical of calderas, but not impact craters. The volcanic pile can be distinguished by its texture — somewhat rougher than the surrounding terrain.

would take place out of contact with Earth, so the signals recorded by the orbiter would be the only signs of success or failure.

Hitting the outer atmosphere at 25,000 m.p.h., the lander endured up to 50 Gs of deceleration for about one minute. Its speed reduced to several hundred m.p.h., it dropped the heat shield 40 miles up and popped a small stabilization parachute. Almost at once, a larger parachute deployed and slowed the probe still further.

At an altitude of 30 miles, the genius of the Russian space engineers became apparent when the parachute was cut loose. The probe, slowed only by a metal disk around its upper structure, fell freely toward the surface in a frantic race with the mounting heat. So dense was the atmosphere, that even without a parachute the probe hit the ground undamaged — exactly as the Russians had planned.

Protective hatches were dropped from positions in front of sensors, and the readings were immediately transmitted 1,000 miles into space where the mother ship recorded them for subsequent playback to Earth. As the temperature slowly penetrated the thick insulation, the harvest of scientific data continued. When the orbiter passed out of range, many minutes beyond the designed lifetime of a half hour, the scientific station continued to send data. It probably failed within another hour, and radio contact with Earth was never restored. But the most ambitious and bold planetary voyage to date had been an overwhelming success.

The television pictures returned were sensational. The local lighting ("as bright as a cloudy June day") was far brighter than expected, and the horizon was visible against the blank sky. The camera was only at a height of a foot or two, so the horizon was obviously not far off. But cameras, both in visible light and the infrared, have become promising instruments for the study of the lower atmosphere and the surface of Venus.

The glamor of space probes during the past 15 years may distract attention from powerful Earth based astronomical techniques. From observatories atop mountains, in high flying aircraft, and hanging from stratospheric balloons, researchers measure the properties of light reflected off the Venusian clouds. At radio telescopes and deep space tracking sites, engineers bounce radar signals off the planet to study its hidden surface.

Some of the most spectacular results have been recent radar images showing Venus with optical resolution as good as the naked eye view of the moon from Earth. Strange new geologic features, puzzlingly reminiscent of terrestrial structures, are teasing planetary geologists. Combined with news from the Soviet landers, this information has brought scientists to the verge of new discoveries about Venus.

The techniques of radar astronomy are fascinating and straightforward. A microwave beam is directed toward a target, and minutes later a faint echo returns. The frequency and time distortions in the return signal, and interference patterns set up in two widely separated receivers, are raw data for some powerful computer techniques that ultimately produce maps of surface roughness and elevation.

The first surface features on Venus were detected by radar more than a decade ago. A highly reflective (and hence probably very rugged) region named Alpha was chosen as the reference meridian for Venusian longitude. This and other features strongly suggested craters, mountains, impact basins and volcanos.

The latest results released early in 1976 show three new features with exciting hints of active continental drift on Venus. One discovery is a gigantic "trough" structure more than 1,000 miles long. Strikingly similar to the rift valleys formed on Earth when tectonism splits land masses, its total length is unknown since it goes beyond the north and south edges of the radar map. Another crater shaped structure almost certainly is a volcano, possibly still active. Rows of hills seem to indicate mountain building in yet another image (each view covers a circle along the equator about 1,000 miles in diameter), while certain linear features look like terrestrial faults.

Thus, the relief on Venus may not be nearly as low and monotonous as previously suspected. The radar data must be interpreted carefully, since its resolution is not great enough to detect most high mountains on Earth, and it can view only a strip along the planet's equator. Nevertheless, some radar scans have shown uplift zones nearly four miles above surrounding plains — comparable to most terrestrial mountain ranges. Perhaps, after all, there is something on Venus similar to Earth's continental drift, except that there are no oceans to clearly demarcate continental plates.

The evidence, of course, is only preliminary. Other observers see only impact basins and erosional structures. New radar probes will be made during future conjunctions, as other areas on the planet are mapped in for greater detail.

What does all this evidence indicate so far? While Venus remains mysterious on many points, certain features are agreed upon by most scientists. But even for these "solved" problems, there are frustrating facts which still do not fit.

The atmosphere is a good example. With a surface pressure of 90 terrestrial atmospheres (equivalent on Earth to a depth of a half mile of water), there is considerable doubt over whether it even warrants the name "air", rather than "ocean". Almost entirely carbon dioxide, the atmosphere has a small percentage of other compounds that give it some special characteristics.

The light yellow clouds seen from Earth are almost certainly droplets of sulphuric acid, concentrated more strongly than in an automobile battery. The actual cause of the yellow tinge, and of the variable ultraviolet absorption, is still unexplained. The top of the clouds is about 37 miles high. As altitude drops and pressure and temperature rise, droplets of sulphuric acid condense and begin to fall as rain for several miles before evaporating in the even greater heat below. This band of sulphuric acid rain is probably several miles thick. Below the rain is a clear band of carbon dixoide; the clouds probably do not reach below 30 miles.

At the surface, winds (or currents) of hot compressed carbon dioxide have been clocked at one to four feet per second. Since wind erosion is really caused by particles carried in the wind, and Venusian air currents do not seem capable of picking up such particles, erosion — in the sense of that found on Earth and Mars — probably does not take place. But the acids in the atmosphere may corrode rather than erode, eating away at exposed rock surfaces. The high temperatures would also encourage the subsurface rocks to creep over millions of years like soft wax, allowing gravity to drag the mountains down, level with the surrounding surfaces.

The rocks on the surface appear to be basalt and granite, sure signs of volcanic activity and of the chemical differentiation associated with the formation of a dense nickel-iron core. This is puzzling since Venus has no detectable magnetic field. Earth's field is often attributed to the terrestrial nickel-iron core; perhaps, as geologists theorize, rapid rotation is also required.

For hundreds of years, astronomers speculated about the length of the Venusian day. Revolving so close to the sun, was the planet locked in to a year-long day which made one side continally sunlit and left the other hemisphere eternally dark? Or, like Earth, did Venus spin quickly? Was the answer somewhere between the two extremes?

Observation of ultraviolet atmospheric markings in the 1950s began to suggest a two to four day rotation rate. But some astronomers speculated that a retrograde (east to west) spin might even be found. Still others did not speculate at all, but built and tested radar equipment.

The first radar contacts with Venus in 1961 allowed the rate to be approximated. The Soviets published preliminary data indicating a rotation rate of about 11 days. More carefully analyzed American data pointed to the astounding conclusions that the spin took more than 200 days, was longer than the year, and was in the "wrong" direction.

If the spin is a much-reduced remnant of an originally high rate (some current theories of solar system formation suggest that all the inner planets once rotated every 10 to 20 hours), the planet had somehow been turned upside down! If the original spin had died out due to tidal friction from the sun, how could the reverse spin have started up?

The best current theory calls for a large, off-center asteroid impact late in Venus' formation phase. This presents difficulties: Such an accident could reverse the spin but could not account for the spin axis still being at a near perfect right angle to the plane of the orbit (an extremely unlikely result in a freak collision). If the rapidly spinning Venus, however, had been flattened at the poles due to centrifugal force, a spin-reversing collision could set up nearly any new axis — but this axis would eventually wander back to its old position because of the planet's oblateness. Such oblateness could have disappeared over the millions of years that passed while the new, slow rotation rate no longer provided sufficient centrifugal force. If this explanation sounds like magic, it's the best there is. Astronomers remain completely baffled.

Although Venus makes one complete rotation every 243 days, it is possibly misleading to call this period a "Venusian day". Since Venus' year is only 225 Earth days long, the combination of rotation rate and orbital motion results in a sunrise to sunrise period of about 117 Earth days. On Venus, the sidereal day is thus about twice the solar day, and the "year" is only two "days" long. Earth's much faster rotation rate makes the sidereal day differ from the solar day by only four minutes.

As Venus' rotation rate became more accurately determined during subsequent conjunctions, astronomers noticed a curious resonance in the length of the spin cycle. In one synodic period (the time from one conjunction to the next; for Earth and Venus it is an average of 584 days) Venus has exactly five solar days. As a result, Venus faces its same side to Earth on every close approach.

Comparisons with Earth's lock on the moon's spin come to mind immediately, though the parallel is by no means exact. The lock is not perfect, since recent figures show that the actual Venusian day is lower than the required rate by a few hours. Furthermore, Venus does continue spinning at a constant rate; by the time it has moved from conjunction to elongation, it has turned its other face toward Earth.

Earth and the sun exert forces of about equal orders of magnitude on the moon, but Earth grabs the moon's spin because of its steeper gravitational gradient. The sun attracts Venus with a gravitational force 50,000 times stronger than that of Earth — yet it seems that Earth is "capturing" Venus.

The best explanation for this close resonance (and for the fact that the Venusian year is within a few hours of being exactly 8/13 of Earth's year) is to appeal to coincidence — an unsatisfactory solution at best. Nagging doubts insist that something vital is missing from the logic involved. For Venus to have been grabbed by any other object through a natural process, its mass must have been unevenly distributed at the time. The size of the necessary asymmetry can be estimated, and it is large enough to have been noticed by its effect on passing spacecraft. But no such gravitational anomaly seems to exist. Perhaps it once did, before the forces of erosion and isostasy smoothed out the plasticlike surface.

Yet another puzzle awaits explanation: the wind velocities in Venus' atmosphere. The broad sweeping bands in the atmosphere of Venus, photographed by the ultraviolet cameras of Mariner 10, Venus 9, and Venus 10, are well known. Over several days before and after the Mariner flyby, a sequence of pictures was taken. Patched into a 30 second movie, they show the dramatic sweep of Venus' clouds as they move around the planet once every four days.

Venus rotates at a speed of only five m.p.h. at its equator, but these cloud markings are traveling at a velocity 100 times that. On Earth, jet streams in the outer atmosphere may occasionally travel 20 or 30 percent faster than Earth's spin, but the energy source for the Venusian velocities is completely unknown.

More than 10 years ago, observers on Earth had detected four to six day fluctuations in the ultraviolet markings. Doppler shift readings off the right and left limbs of the planet produced results which confirmed atmospheric motion at several hundred m.p.h. How could Venus' upper atmosphere be propelled around the planet at such disproportionate velocities? Initial meteorological computer simulations could not account for speeds anywhere near as high. The dynamics of this atmosphere, which should have been so simple, were increasingly puzzling. Although recent computer models have been able to simulate the effects thought to have been seen on Venus, they seem rather strained and artificial. A far simpler solution to the whole problem of fast atmospheric rotation has now been proposed, claiming that the fast rotation is an illusion! The actual cloud speeds may be more in line with the slow surface velocity after all.

Clearly, something does propagate around the planet with a four day period. Perhaps it is an illusion of motion caused by shock waves which somehow alter the ultraviolet absorptivity of a slowly moving cloud layer. The actual cause of the dark and light stripes remains unknown. But what about the Doppler measurements from Earth? This theory disputes not the actual readings, but their interpretations. The scientists who originally reported the data may have ignored a vital factor which weakens their conclusions.

The redshift of the light from the receding eastern limb, and the blueshift of the light from the approaching western limb, both indicate a fast retrograde rotation *only under* the assumption that sunlight reflected off the clouds does not have any Doppler shift itself. But the sunlight reflected off the edges of Venus is not from the sun's full disk! Near the terminator (the day/night boundary), the sunlight is coming from only a fraction of the sun's face; the rest of the sun has already set. That fraction is sending shifted light, since the limb of the sun is moving. The light from Venus received at Earth thus has a real Doppler shift, but a shift indicating velocity on the sun, not in the clouds of Venus!

The actual cloud mass *does* seem to have a four day pulse, but it is a slow up and down motion. Lateral movement on the equator, from day side to dark side, probably takes about 60 days. Clouds on the dark side sink lower because they are not being boiled by the sun, and in the lower atmosphere, they pick up heat convected by the winds — with the odd result that the cloudtop temperatures are several degrees warmer on the dark side!

Encouraged by the presence of such thick clouds, science fiction writers of the last generation have vigorously and skillfully exploited the theme of Venusian oceans. So appealing was the idea that it was used in many stories even after new data had indisputably ruled out the existence of liquid water on Venus. Scientific discoveries seemed to have banished these oceans into the realm of myth. New calculations, however, indicate that the oceans of Venus may indeed have been real; they have just been dry for hundreds of millions of years.

If Earth and Venus were initially similar in composition — and there is great debate over this point among astrochemists — the process of differentiation and volcanism on Venus might have produced as much water as on Earth. This water may have existed in liquid form for more than one or two billion years, rolling beneath a sky of carbon dioxide, nitrogen, ammonia, methane and other gases.

But today Venus is trapped in a vicious temperature cycle called the *greenhouse effect*. If a rise in temperature frees carbon dioxide from subsurface rocks (where a similar quantity remains on Earth to this day), it would cause the atmosphere to become more opaque to infrared light. Sunlight streaming in through the atmosphere would warm the surface; the resultant infrared rays could not escape through the atmosphere, causing the temperature to climb still further. Once the oceans boiled and the remaining carbon dioxide broke free from the rocks, the lid on outgoing heat would be sealed tight, and the temperature would climb several hundred degrees.

But without this lid, the *black body* (radiation only) temperature of Venus should not have averaged much above 150 degrees Fahrenheit, and oceans would have remained. If we assume a cloud cover with a high albedo, much of the sunlight would not reach the surface, or (without the greenhouse effect) could be reflected harmlessly back into space. The temperatures of the polar regions on this wet Venus could have been below 100 degrees Fahrenheit, well within the range of terrestrial life forms.

All the terrestrial effects associated with liquid water would probably have been present on such a proto-Venus: hurricanes, mountain glaciers, gentle temperature extremes, rivers washing salts and sediments into the oceans, and the primordial organic soup of amino acids and proteins that laboratory experiments have shown can form anywhere there is liquid water. If current theories about the origin of life are correct, biological processes might have begun in these Venusian oceans. Depending on mutation rates and the fumbling, but upward, trend of evolution, multicelled plants and animals might have begun to evolve before the greenhouse effect arrived and the oceans boiled. If this hypothetical image was once true, how could traces of these ancient life forms be found today?

If Venus ever had rivers and oceans, the river beds and ocean basins should still be there. Flat areas reminiscent of lunar maria have indeed been detected by radar. Perhaps, unlike the misnamed "seas" of the moon, the maria of Venus were truly once filled with water. Clearly, more data is needed.

Since the oceans would have vaporized only long after the tumultuous era of the great asteroid impacts three billion years ago, there would probably be few meteor craters on these dry ocean floors. A small number of craters on a dry ocean is a disadvantage in searching for traces of life; impacts would have torn great holes into these maria and thrown out rocks from deep underground and far in the past, greatly facilitating the search for the only traces of life that could survive the heat and pressures of modern Venus.

This evidence would consist of fossils. Living creatures often reorder rocks and minerals into shapes that testify to the former presence of life, even after all traces of the organic compounds have disintegrated. The shells and skeletons of Venusian life, if it ever existed, might still be around.

Finding such evidence is another matter. If this wet Venus had an appreciable land area and frequent rains, a billion years' worth of sediments could be miles thick. If Venus was once completely covered with oceans which had worn away all the dry land, the deposit of sediments would be very slow or even nonexistent, allowing organic remains to completely decompose without a trace. But if conditions were just right, this biological episode in Venus' history would have left unmistakable remains for exobiologists to study.

On Earth, studies of ancient marine fossils can give paleontologists information on ocean temperatures and the length of ancient days. Samples from widely separated points can testify to the extent of ocean currents, thermal gradients, and intervening land masses. The same techniques that have been proved out in the oceans of Earth may find applications in the next century's studies of the dead oceans of Venus.

If Venus had these oceans in the past, the question remains: Where did all the water go? Water vapor in the atmosphere could be slowly broken apart by sunlight into its constituent elements. The hydrogen would simply have escaped into space over a period of a billion years or so; the oxygen could have recombined with surface rocks. But if Venus ever had as much water as Earth now has, it would require a planetary layer of oxidized materials many miles deep to absorb all the oxygen.

Alternately, of course, the ocean theory may be completely wrong, and Venus may never have had much water. Different theories of solar system formation can give different ratios of Venusian water to terrestrial water. The oceans may never have been there, or the temperatures may always have been too high. (But then another agent for high temperatures would have to be invented.)

Meanwhile, the abundances of other atmospheric constituents are not really very different between Venus and Earth. Most of Earth's carbon dioxide is safely locked up in limestone and seashells; if it were to break free through a rise in the planet's heat, it would increase the atmospheric mass 70 times.

Nitrogen makes up 75 percent of Earth's air, and the same amount would remain in the air in such a new atmosphere. However, its proportion would be reduced to less than one percent due to the increase in the amounts of other materials. This figure is probably close to that in Venus' atmosphere.

The vaporization of all Earth's water would add another 300 atmospheres, and life on Earth would cease forever. Free oxygen would be gobbled up by the hot minerals covering the barren surface. Carbon dioxide would add to the greenhouse effect. Once started, this runaway process would probably be irreversible.

Such a nightmarish scenario is all the more reason to study Venus in detail. If Venus once did have oceans and life, some unknown factor must have upset the balance and destroyed the ecosphere. The solar constant may have increased; the cosmic catastrophe which reversed the spin rate may have overheated the surface or released enough carbon dioxide to maintain a temperature climb; or, the biological processes may have upset what might have been a precarious balance too close to the sun.

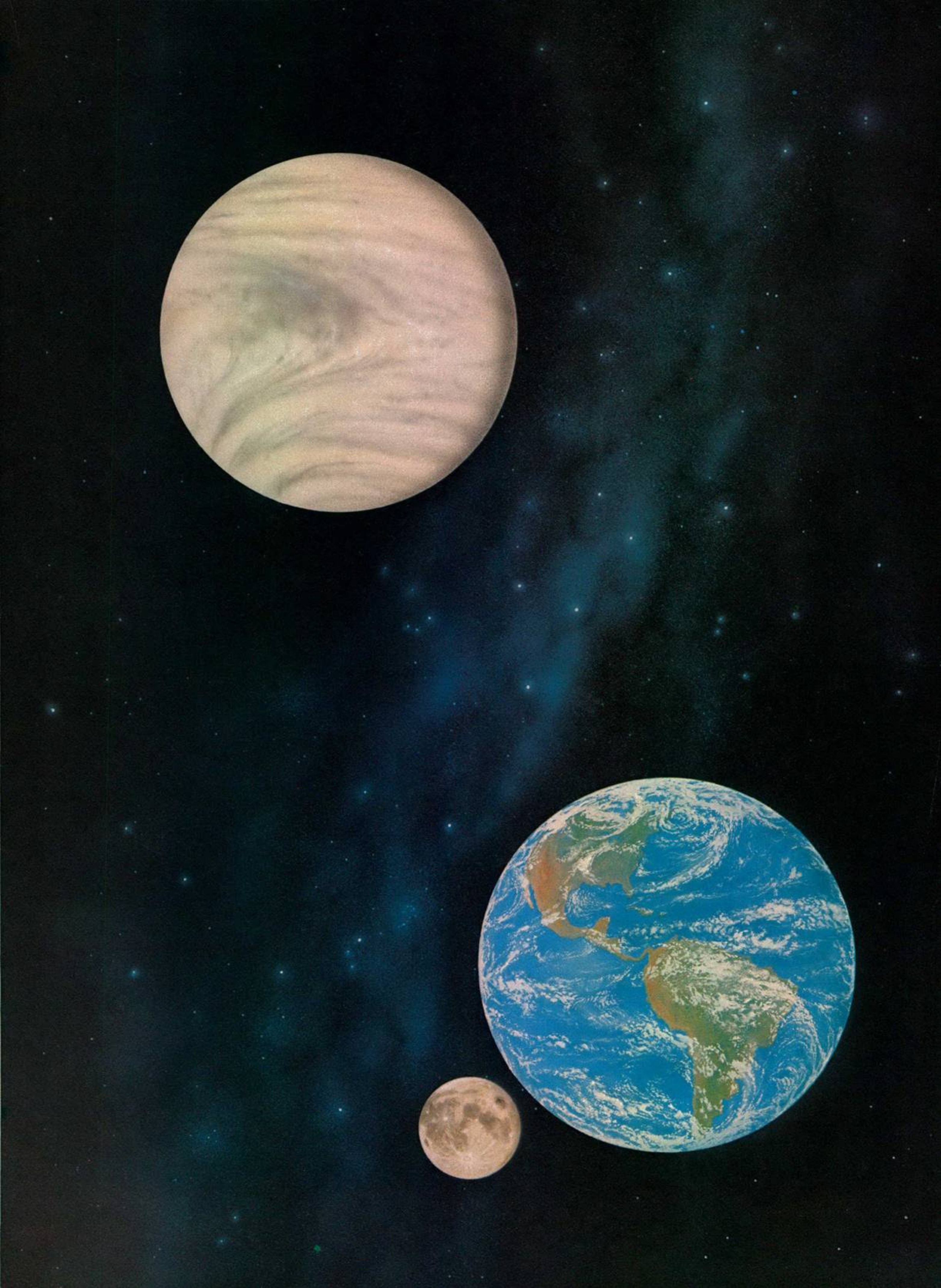
Seeing how human activity on Earth may be affecting our own ecosphere, scientists would dearly like to know how to avoid turning Earth into another Venus. It might be critically important to find out.

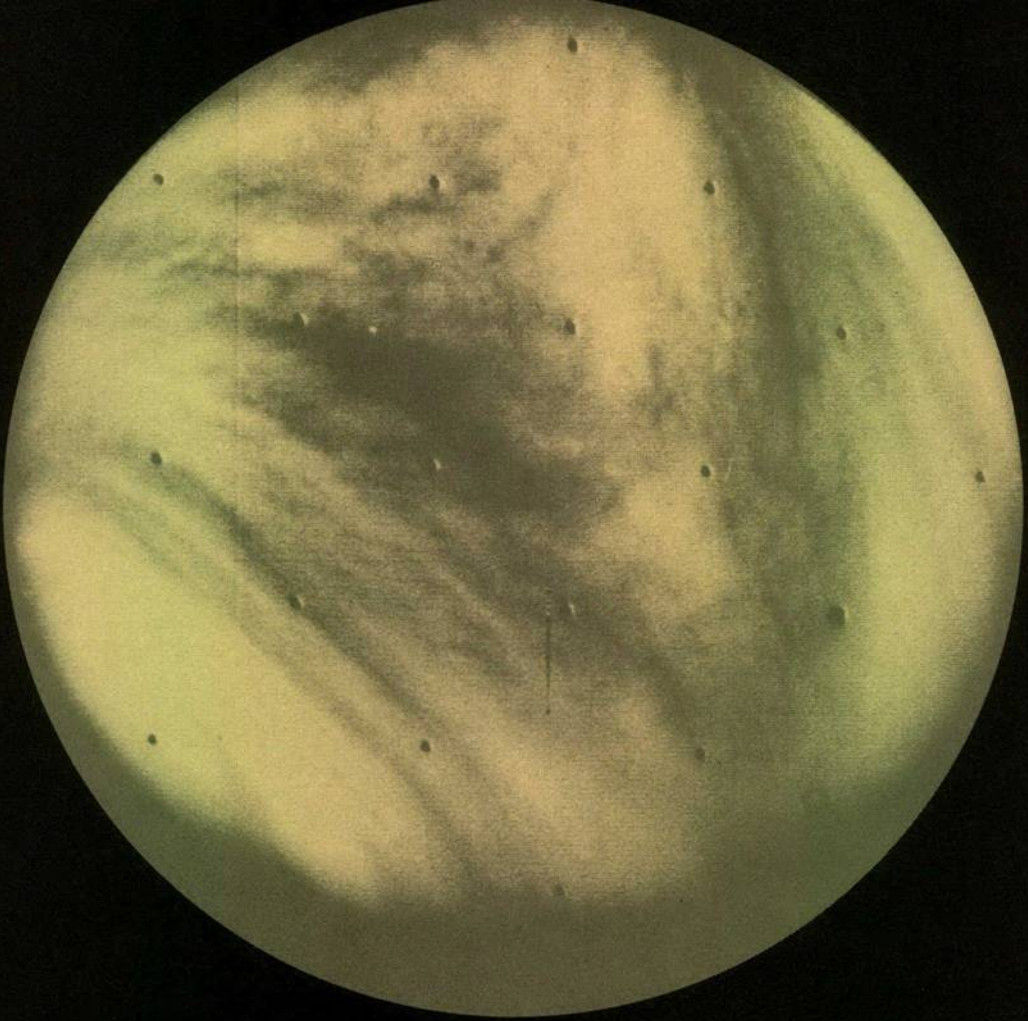
The opposite process of planetary transformation might also someday be possible. Early in the space age, astronomers proposed a project to "terraform" Venus, changing its environment into a suitable one for human habitation. This could not be done with massive air conditioners and importation of oxygen bottles; other techniques would be needed.

Blue-green algae were to have been seeded in the upper atmosphere of Venus, where under good conditions they could have floated, reproduced and spread across the planet. They would have broken down the carbon dioxide, weakening the grip of the greenhouse effect. Ultimately, rains would fall on Venus and the clouds would break.

Unfortunately, the only rain likely to fall on Venus is a rain of sulphuric acid, inimicable to blue-green algae and humans alike. There is not nearly enough water left anywhere on the planet or its atmosphere.

Venus and Earth — once thought of as twin planets — are now known to be very different; little besides the two planets' size and mass are similar. Venus has a dense atmosphere, little water, no magnetic field and extremely high surface temperature. Earth has an atmosphere only 1/100 the density of Venus', much water, a strong magnetic field, and a temperature comfortable to carbon based life. Artwork by Victor Costanzo.





This, however, may only delay the project a few centuries at most. It would be necessary to import the water in the form of an ice asteroid several miles across from Saturn or beyond. Perhaps it could be smashed into the planet in such a way as to speed up the spin, power up the magnetic field, and set up some protective Van Allen belts. Then the blue-green algae (a special strain tailored in genetics laboratories and resistant to sulphuric acid) would get their chance!

New space probes are already being built to investigate the old and new mysteries of Venus. Every year and a half, Venus and Earth swing around into the same relative positions, opening up a launch window of several weeks' duration, permitting a three month voyage from one planet to the other. Given enough energy, we could launch to Venus at nearly any time, but this cycle is only concerned with the most economical opportunities.

The next Venus window will open near the end of 1976. Recent Soviet statements indicate they are still studying results of their last missions and will not have new vehicles ready until mid-1978. Despite traditional heavy curtains of secrecy about future space plans, the future goals of Russian astronomers can be approximated from public statements during the last mission.

With orbiting probes essentially blinded by the clouds, and landing probes facing a quick death, Soviet scientists have picked a third environment for exploration: the atmosphere. In cooperation with French scientists, they are building inflatable aerostats (balloon platforms designed to send back data via orbiting relay satellites over a period of days or weeks).

The latest Venus probe data has pinpointed the most productive levels for exploration. Initially, the balloon (called Eos) would carry its 50 pound instrument package through the clouds at an altitude of 30 miles, where the temperatures and pressures are close to those of Earth's surface. Batteries could provide power for a week; longer missions could use solar cells (although corrosion would be a problem) or nuclear power.

Once the more hospitable regions of the atmosphere had been charted, the probe could release most of its buoyant gas (probably hydrogen as there would be no danger of fire in an atmosphere devoid of free oxygen), and descend to more interesting realms. Passing quickly through the region of the sulphuric acid rains, the probe would reach an area about 20 miles high, where temperatures had climbed to 300 degrees Fahrenheit and pressures were 10 times those of Earth. Survival at this level would be short, and the orbiting radio relay would be visible only for a few hours every other day.

The primary mission of this suicide altitude would be to photograph a panorama of the surface and of the underside of the cloud layers in the near-infrared and visible wavelengths. Areas, miles on a side, would be visible during the probe's slow drift. One sought-after datum would be the frequency of small craters. Volcanos, vents and faults would be prime targets for discovery. Evidence of liquid flow (whether lava or water) would be sought, and actual pools of liquid metals or hydrocarbons might be seen. Most important on a planet like Venus, the probe could detect features that are completely unexpected.

Although there is no indication that the Soviets are working on it (and there are definitely no American plans for attempting it), one more instrument would certainly produce the most haunting perceptual input from space since the first photographs from other worlds began coming back a decade ago. The instrument in question would be a simple microphone, tuned to subsonic and ultrasonic wavelengths beyond the range of the human ear.

What does Venus sound like? The density of the atmospheric ocean would provide acoustic conduction more akin to that of Earth's deep seas than air. Would we hear the shriek of winds, the groan of strained rocks, or the roar of volcanos? Would we hear thunder, or the bubbling of escaping gases in a liquid metal pool? Would we hear only the patter of sulphuric acid rain on the roof of the gondola carrying the microphone? Whatever sounds did come back to Earth would be powerful stimuli to Earthbound imaginations, as they complete the perceptual pattern of what it would be like to really be on another world.

Besides listening to the atmosphere, a crucial requirement for future surface exploration would be to listen to the land. The use of a seismometer to detect internal earthquakes could tell an incredible amount about actual Venusian tectonics. A network of two or three active seismic stations would be even more valuable. However, the Soviets haven't yet landed a seismometer on any celestial object, and it could be 20 years before one is in service on Venus.

A family of six American space probes will be launched toward Venus in the window after next, which will be open during the summer of 1978. These Pioneer-class spacecraft will make investigations of the planet's interior and of its atmosphere; there are no current American plans for surface exploration.

One probe, Pioneer 12, will go into a polar orbit around Venus late in 1978. It will dip to within 120 miles of the surface, searching for gravitational irregularities which can tell geologists about the internal layering of the planet and about its external shape and mass distribution.

Pioneer 13 is a quintuple spacecraft. When it arrives at Venus five days after Pioneer 12, it will already have broken up into five separate parts. The mother ship (called the bus) will have ejected three small and one large entry probes, targeted for widely scattered points across the face of the planet.

As they plunge into the atmosphere, the probes will measure pressure, temperature, deceleration, cloud extent, altitude and density, and the heat exchange between the sun and Venus. One probe will also carry a mass spectrometer and a gas chromatograph to provide details about the atmospheric components. The bus will also have a mass spectrometer for measuring the upper atmosphere before it burns up (it has no heat shield).

The three small probes will fall straight down to the surface, returning data directly to Earth until impact. The large probe will have a parachute to give it more time for making its detailed readings. Survival after landing is not planned, but it could occur as a bonus. The large probe in particular could make further readings on the composition of particles kicked up from the surface by its impact.

Later Venus probes in the Mariner series (perhaps a Mariner 13 could be scheduled early in the 1980s) might make radar maps of the surface. In the bistatic mode, a large parabolic antenna on the spacecraft could pick up echoes from radar beams transmitted from powerful stations on Earth. New types of radar could operate directly from the spacecraft, given a high power source.

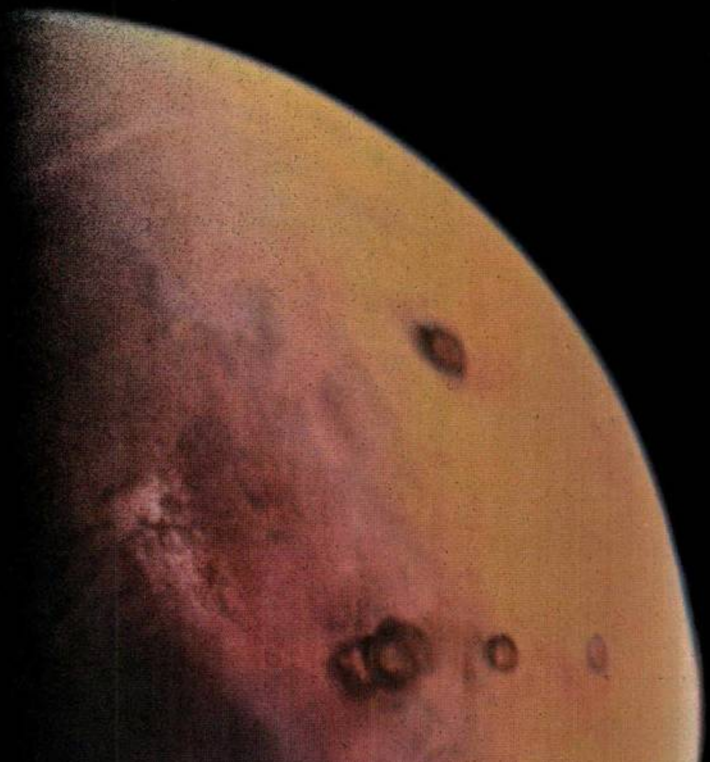
There are two possible approaches to the problem of long term survival on the surface. Specialized equipment, capable of surviving for days exposed directly to 900 degrees Fahrenheit, could be designed. Alternately, refrigeration would have to be provided, requiring extremely advanced nuclear power supplies or contamination of surroundings by evaporative water — a short term solution in any case.

Balloon-borne probes promise a profitable and productive halfway house, since they could float high enough to provide Earthlike environments. Complex robot laboratories controlled by computers and advised by scientists on Earth could analyze samples brought up from the Venusian surface.

Transportation between the ground and the aerostatic balloon might be relatively easy. The lander, designed to survive a quick dash to the surface, could inflate a hydrogen balloon and automatically load the sample cannister into a small gondola. Rendezvous and docking between the propellor-driven mother craft and the sample balloon provides some intriguing engineering problems, but the results could well be worth it — especially if the rock samples came from the ocean basins which once may have cradled life.

The blank face of veiled Venus belies a planet of infinite mysteries. The answers to many of these puzzles may be crucially important to questions of life on Earth. Venus is neither simple nor boring. Like every other world which men have explored, it is full of unexpected wonders. The age of the interplanetary surprise is far from over; Venus will astound us again and again.

James Oberg, a computer specialist and science writer, is currently helping to develop payload application software for space shuttle on-board computers at the NASA Space Center in Houston. He works as a computer specialist in nuclear/aerodynamic/laser stimulation and has taught courses in computer management. Oberg is a contributing editor to ASTRONOMY.



VIKING ORBITS MARS

by
William K. Hartmann

Although most press coverage of the Viking mission will stress the landing attempt, exploration started weeks earlier with both the basic research and attempt to find a safe landing site.

Viking discoveries began even before the spacecraft reached orbit. *Far encounter* pictures, made at about the moon's distance from Earth, showed Mars half illuminated (a view never seen from Earth). Viking approached from the morning side of Mars, and photos showed light, hazy veils and bands over more of the planet than expected by some scientists. Low-floored impact basins, such as Hellas and Argyre, showed startlingly bright patches of frost and/or low haze as they emerged from Martian night into morning. By midday (the phase most clearly seen from Earth), such frost and haze "burns off" in the Martian sun.

Other photos showed unexpected details among the four huge volcanic mountains of the Tharsis region. All four mountains showed up as very dark spots — similar to early Mariner 9 views when the dark, lava covered volcanos protruded through bright clouds of the 1971 Martian dust storm. But this year there was no dust storm! Why were the mountains so dark? They may have been protruding through morning mists that lighten the general tone of lower topography. Alternatively, they may have been stripped of light dust or coated with dark dust as a result of Mars' active winds. Arsia Mons, the southernmost volcano, was especially altered since 1971-72, with lobes of dark material extending northeast and southwest from its base. Again, these are probably products of dust removal or deposition.

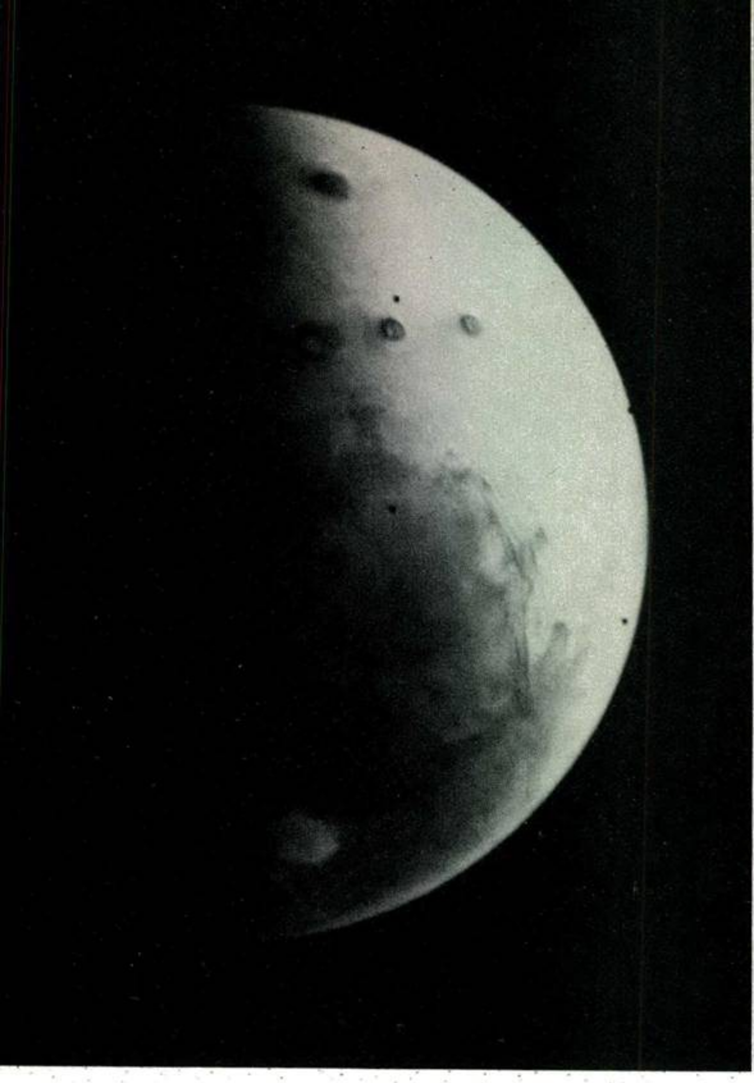
This color rendition of Mars as it would appear to a person approaching it was made from three separate black and white pictures taken through color filters — violet, green and red — on June 17 as Viking 1 closed to within 348,000 miles (560,000km) of the red planet. The black and white frames were taken just seconds apart by one of the Viking orbiter's two television cameras and radioed back to Earth. Corrections were made in a computer for the color response of the camera; the color photograph was then reconstructed on a TV screen. The Tharsis Mountains are clearly seen — a row of three huge volcanos standing about 12-1/2 miles (20km) above the surrounding plain. Toward the top of this picture is Olympus Mons, Mars' largest volcano. The circular whitish feature at the bottom of the disk is a large impact basin, Argyre. The area around Argyre is slightly brighter than elsewhere, probably because of the presence of discontinuous thin carbon dioxide ice on the surface. Several atmospheric features are faintly visible. West of the southernmost Tharsis volcano (left) is an irregular white area (which has been seen on two successive days by Viking 1) that has been interpreted as a water ice surface frost or ground fog; the faint, curved bands in the lower half of the picture probably are thin cirruslike clouds. The yellow at the edge of the planet's limb is somewhat artificial, caused by extreme variation of brightness in the violet photograph. NASA photograph.

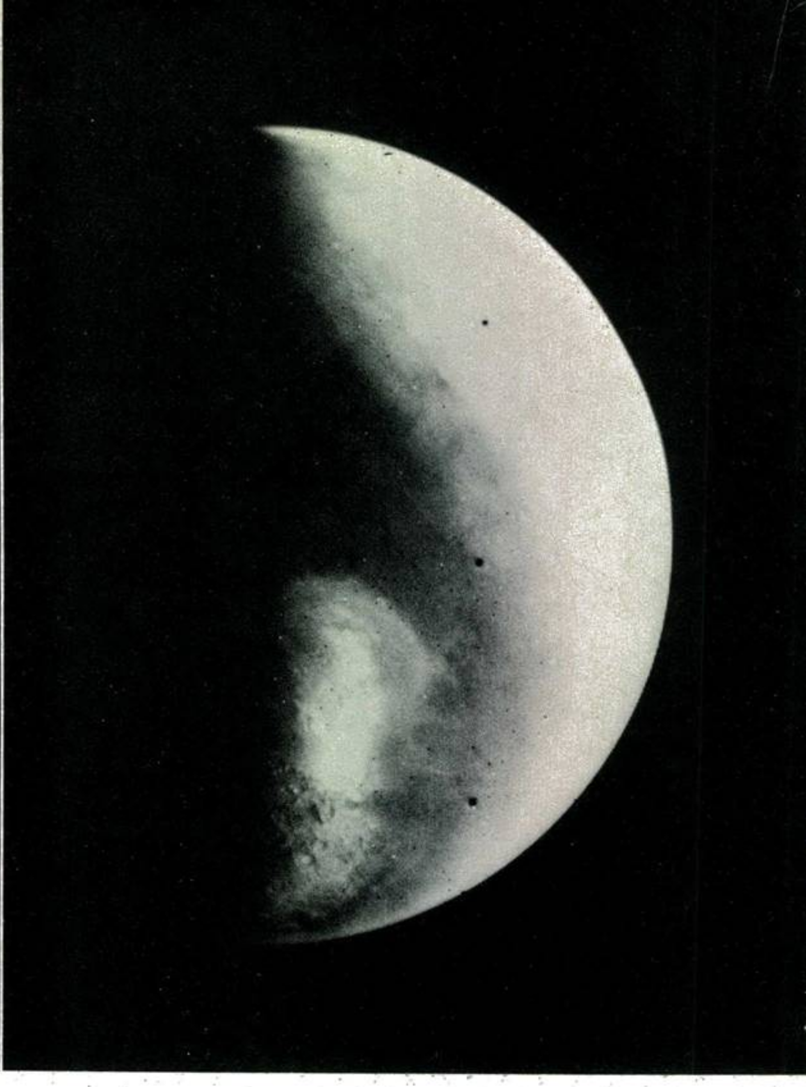
The far encounter pictures were especially useful in filling a gap in Mars data: Previous missions had produced either "postage stamp" close-ups too detailed to show global patterns, or global images from too far away to reveal relations between dark markings and geologic detail.

Following far encounter studies, Viking 1 entered Mars orbit on June 19, 1976, with a 38 minute rocket burn. This slowed the spacecraft into a 43 hour orbit ranging from 930 miles (1,500km) to 31,000 miles (50,600km). A three minute burn on June 21 brought the vehicle into an orbit that passes over the landing site every 24.6 hours, ranging from the same low point to a high of 20,400 miles (32,800km).

Early orbiter measurements indicated a greater quantity and diversity of water vapor than had been expected in the Martian atmosphere. Viking scientists interpreted this as evidence of daily exchange of water from soil to atmosphere, as might happen with diurnal melting of ice. The finding suggested that Viking may have arrived at a good time to look for biological activity, which is presumed to require water.

The prime choice for a Viking 1 landing site — selected many months before Viking neared the planet — was a relatively smooth plain known as Chryse





(rhymes with icy). It is several thousand feet lower than most Martian terrain, meaning that the air pressure is higher than average. Though this pressure may be only one percent of that found at Earth's sea level (less than that outside the cabins of the highest commercial jets), it is high enough to allow liquid water, should the temperature rise high enough. Liquid water, of course, would favor biological activity if there is any life on Mars — and the search for life is a prime motivation of the Viking mission.

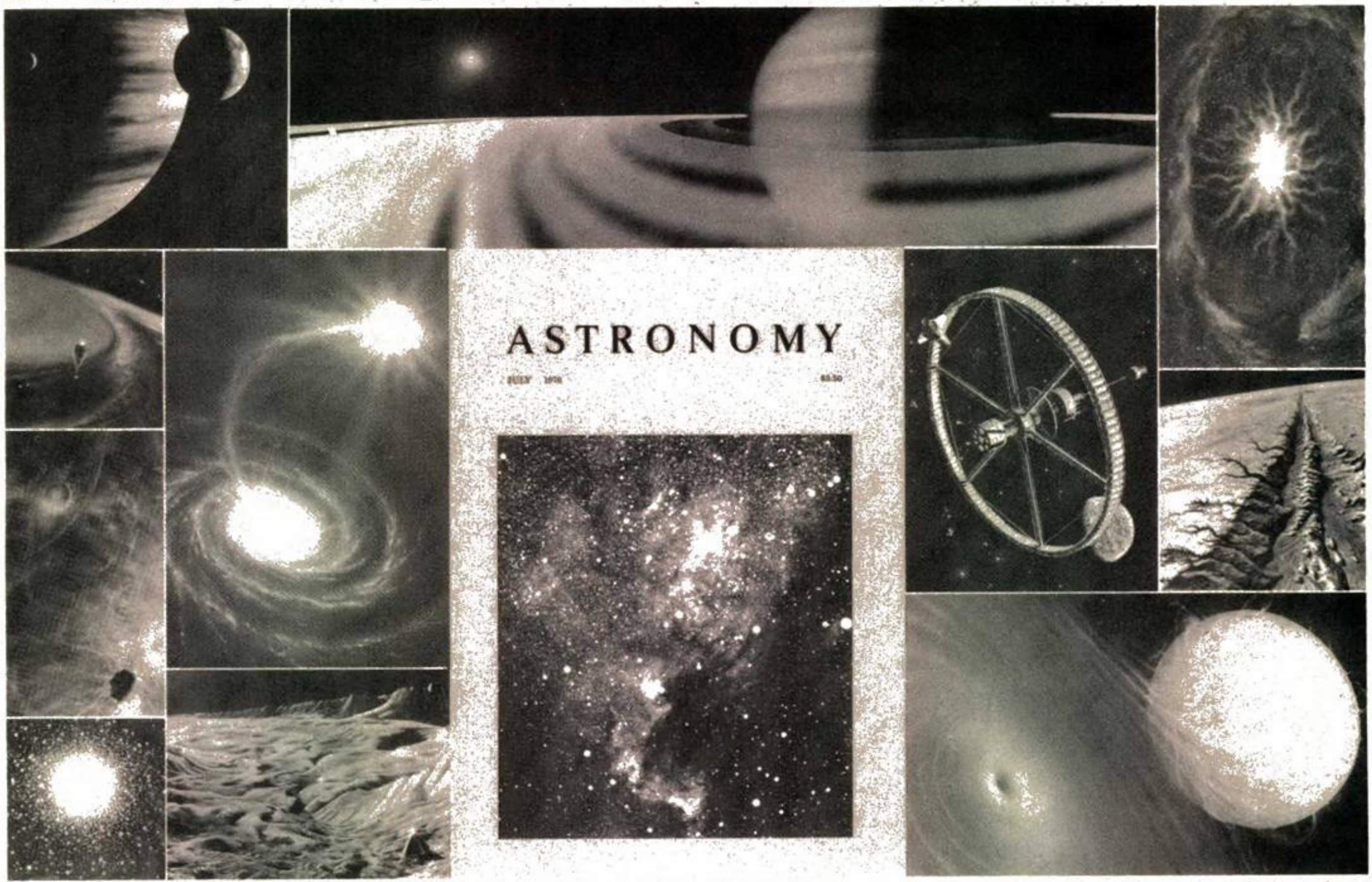
A second favorable aspect of the Chryse region is that it is only 20 degrees north of the Martian equator. On warm afternoons, temperatures should exceed the melting point of water. (The highest temperatures actually recorded by Viking through June 21 were around -31 degrees Fahrenheit, but these were morning temperatures.)

Third and most important, Chryse lies at the mouths of four of the largest channels on Mars, named Shalvatana Vallis, Simud Vallis, Tiu Vallis, and Ares Vallis. These channels are believed to be beds of ancient rivers that ran with water perhaps 100 million years ago. If so, the water must have emptied into the Chryse region, perhaps forming a temporary sea or possibly evaporating rapidly. Thus, the Chryse region might have a good chance of presenting ancient biochemical effects that required water.

For these reasons, as Viking approached Mars, there was intense interest in seeing what detailed, close-up pictures of the Chryse landing site would reveal. Would Chryse be as smooth as had been hoped? The maximum slope that Viking could land on was about 20 degrees, and the maximum size rock that would clear the undercarriage without punching a hole in the lander was about 10 inches. Could such obstacles be avoided?

The first pictures to help provide an answer came on the night of June 22-23, after Viking went into orbit around Mars. Due to improved camera optics and electronics, they showed more detail than anything provided by Mariner 9. What they showed was somewhat frightening to Viking mission planners (see page 4 for details). Scientists are concerned, on the one hand, that the small scale structure of Mars is unexpectedly rough — but, on the other hand, there is great excitement at the new detail discovered. Some pictures have about 10 times the resolution of the Mariner 9 frames. Cinder cones and other volcanic features have been found. Unknown craters have been recognized in regions that were obscured by haze during previous missions. Most exciting is confirmation of Mariner 9's finding features such as apparent ancient shore lines along Martian channels, indicating that abundant water flow once occurred and carved out major landforms in some regions. Explanation of the geologic processes or climate changes that produced water in Mars' ancient past will be a major goal of Viking explorations.

Man's Dream of Worlds Unseen



Carl Sagan and John Clark are a team.

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GAZER'S GAZZETTE

Exploring the Milky Way

by
Richard Berry

On warm summer nights far from the lights of the city, the sky is dominated by an awe inspiring band of light stretching across the sky — our own galaxy, which we call the Milky Way. The Milky Way reveals more detail to the casual observer than other galaxies do through the world's most powerful telescopes — yet surprisingly few star atlases and observers' handbooks devote more than a short amount of space to it! And no maps seem to exist that can give much help to the binocular user or astronomy enthusiast with a portable telescope. In short, the Milky Way has been ignored by observing books and charts. You'll find, however, if you take the time to look, that the Milky Way is an extremely rewarding subject for study with a very wide range of instruments — from your own dark adapted eyes to binoculars, small telescopes, and richest field telescopes. It's an inexhaustible source of objects for viewing with even the largest telescopes.

The first thing you notice when you look carefully at the Milky Way is that it is by no means a simple object. It has variations in brightness, dark spots, bright spots, places where there are too many stars to count — and other places where there are no stars at all! We couldn't expect it to be simple, of course; it's a whole galaxy spread out before us, with all the detail and complexity you'd find in a swarm of 100 billion stars.

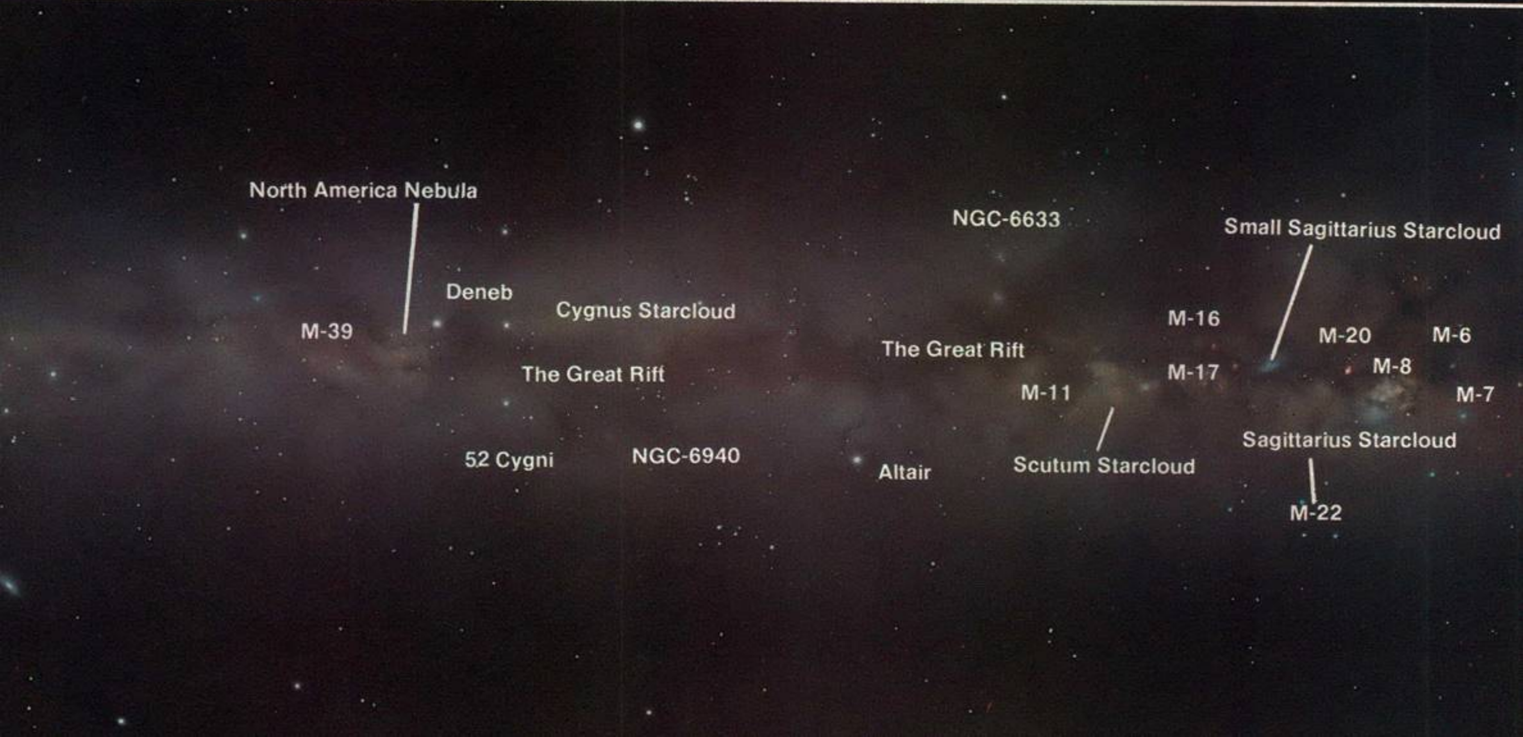
When the Milky Way rises in the northern hemisphere it comes up almost parallel to the horizon. Cygnus and Cassiopeia rise first; then Aquila, Scutum and the claws of Scorpius, and finally the rich brilliant central regions of the galaxy in Sagittarius. By August, it's high in the sky by the time darkness falls, and the southern parts in Scorpius and Sagittarius cross the meridian just after the end of twilight. By midnight the brilliant starclouds of Cygnus pass through the zenith. For campers, vacationers and city dwellers (perhaps getting a rare chance to be out of the city and under clear, dark country skies), August is the time to observe the Milky Way.

We'll begin our tour of the galaxy in the south, not because it's brighter and contains more objects, but because it is somehow fitting to start near the center of the galaxy. For the benefit of those living in the northern states, we'll only go as far as -35 degrees declination.

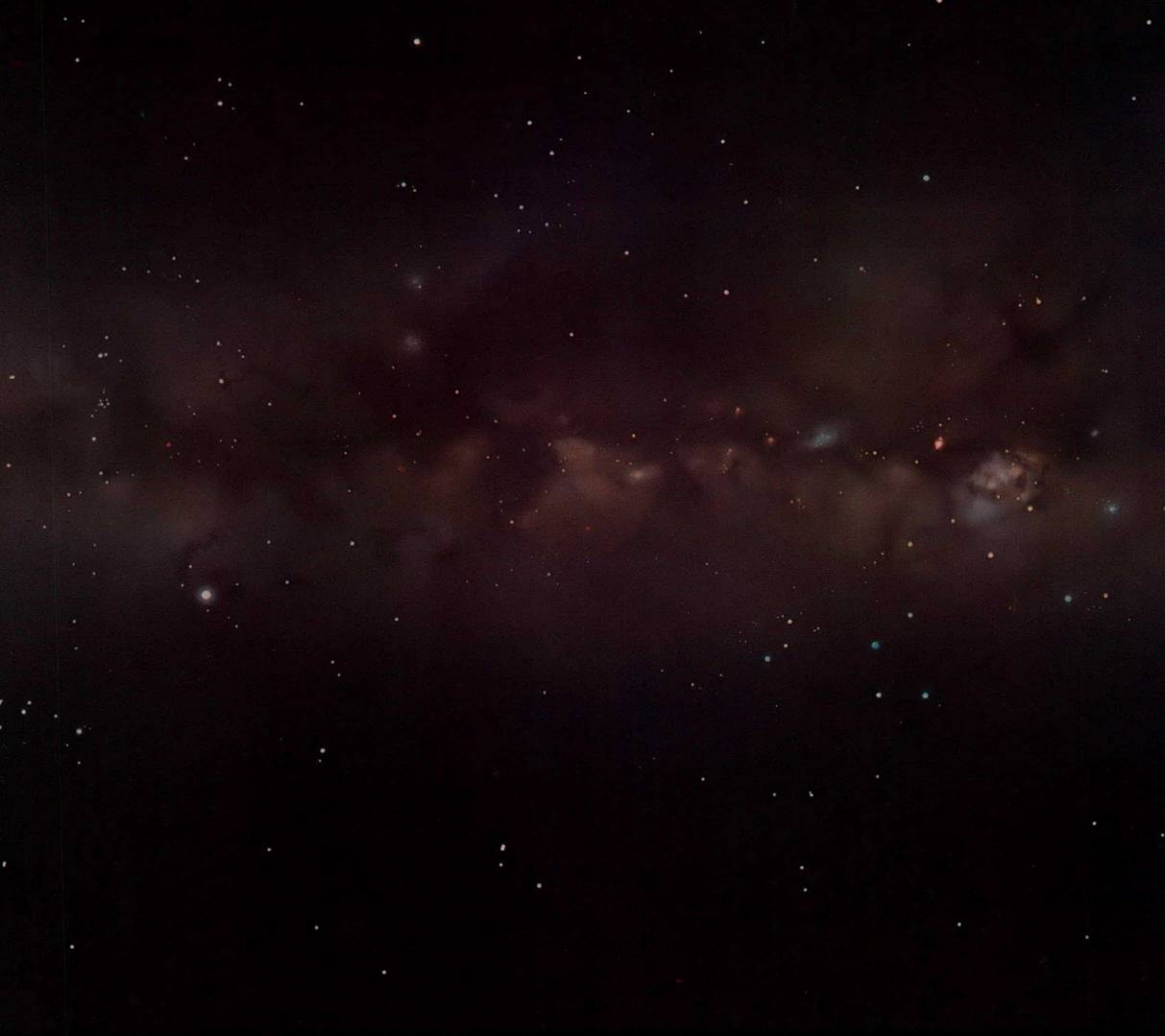
For visual observers and binocular users, Sagittarius' teapot forms a valuable starting point, much as the Big Dipper does for the north circumpolar stars. Looking south, the handle of the teapot (on the left) is composed of four stars, while the spout (on the right) contains three stars. Looking above the spout, you'll see a puff of celestial "steam" about five degrees long. This is the richest and most brilliant starcloud in the Milky Way, known as the Great Sagittarius Starcloud. From northern latitudes it may not look as bright as some of the starclouds in Cygnus, but from latitudes where it passes overhead (and isn't dimmed by the atmosphere), it *is* brighter. Surrounding it are darker areas where the light from stars is absorbed by dust lying along the plane of the galaxy. The Great Sagittarius Starcloud shines through a "hole" in the dust. In fact, if the dust wasn't there absorbing light, the entire Milky Way would shine more brightly than this starcloud does now.

If you use binoculars — or even just your eyes if they're sharp — you'll have already noticed the Lagoon nebula (M-8), located only a few degrees north of the starcloud. The Lagoon is a cluster of stars surrounded with a delicate glow or haziness — actually an H-II region where hydrogen fluoresces in the intense ultraviolet glare of the newly born

One of the richest parts of the Milky Way stretches from the tip of Scorpius' tail to Scutum. M-6, M-8, M-20, M-16 and M-17 lie very close to the galactic plane, almost defining it. The Small Sagittarius Starcloud shows a "monstery" aspect in shades of delicate blue — the result of young hot stars in it. Note that along the galactic plane, dense obscuring dustclouds block our view of the galactic center. Photograph by Orien A. Ernest, copyright© 1974 by AstroMedia Corp.



North America Nebula
NGC-6633
Small Sagittarius Starcloud
Deneb
Cygnus Starcloud
M-16
M-39
M-20
M-6
The Great Rift
M-8
The Great Rift
M-17
M-11
M-7
Sagittarius Starcloud
52 Cygni
NGC-6940
Altair
Scutum Starcloud
M-22



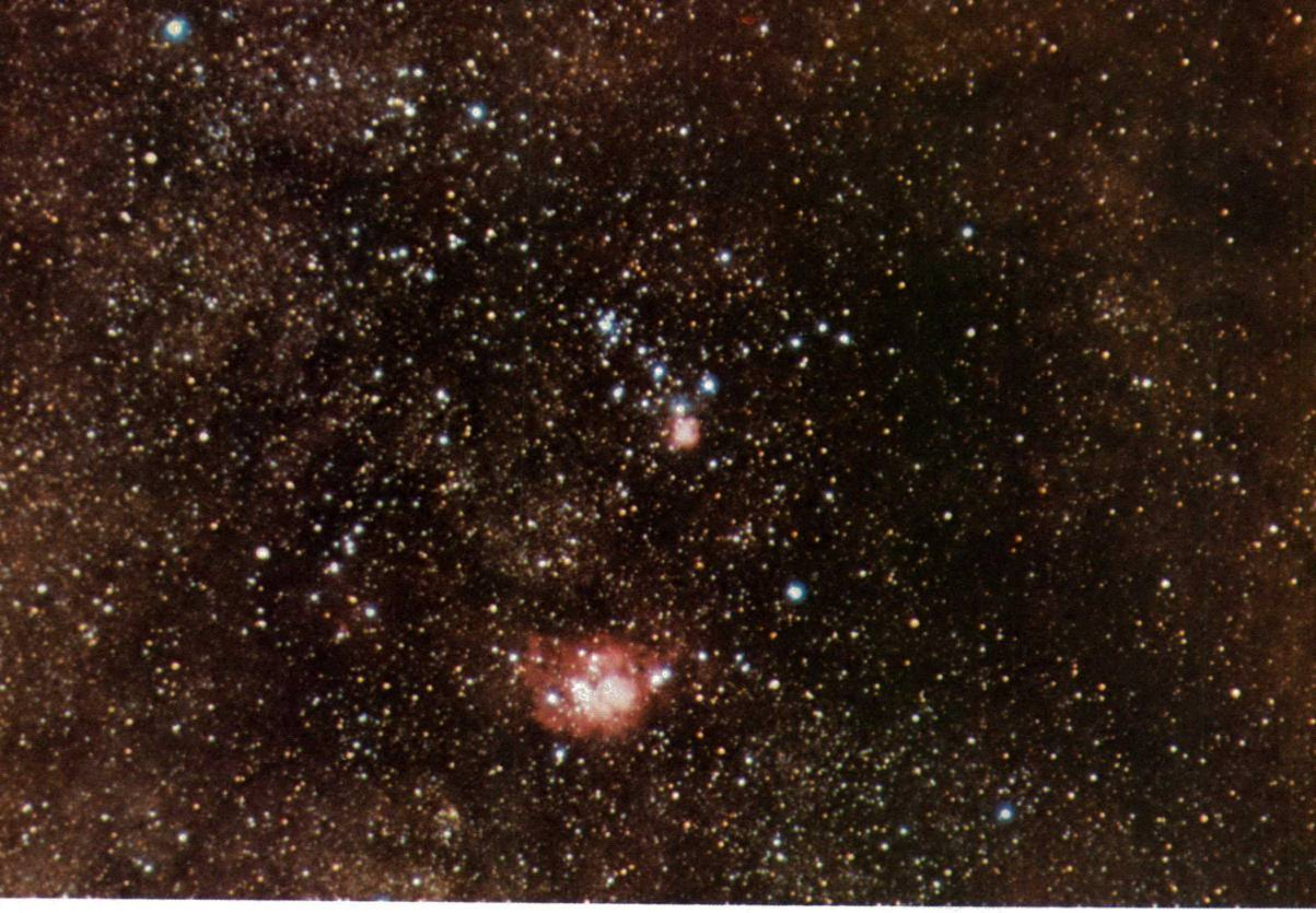
The artist can render best the visual appearance of the Milky Way, shown here stretching from Sagittarius through Cepheus, encircling 1/3 of the sky. The combination of delicacy and detail, seen by the eye from a site of superb quality, is never captured on film. The key (lower left) locates some of the major features that you can easily see by eye or with slight optical aid. Artwork by Adolf Schaller.

star cluster at its center. Just a bit farther north, and quite a bit fainter, is the Trifid nebula (so-called because it is divided into three parts) and a tiny open star cluster, M-21. But let's not get carried away indicating specific sights; these fields are so rich that the slightest shake or bump of the telescope will bring new objects into the field.

Let's start again from the spout of the teapot. This time begin at the star where the spout joins the pot (Delta). Swing past the tip of the spout (Gamma) and about twice as far again; there, a bright open cluster (M-6) will be waiting for you. Nearby are four or five smaller and fainter clusters, easily seen in a small telescope or richest field telescope. Swing south and east a few degrees, and M-7, a really brilliant naked eye cluster, will dazzle you. In a big telescope, both M-6 and M-7 fill the whole field, as the Pleiades do in binoculars.

Where in this area is the exact galactic center located? In visible light there is nothing to mark it, although it can be "seen" in the radio and infrared that penetrate the galactic dust lying between us and the center; the spot is actually about two degrees north and four degrees west of the tip of the teapot's spout. What a sight it would be if we could see it!

Another object that's easy to find is the globular cluster M-22. The top of the teapot's lid is marked by Lambda; a bit to the north and east you'll find the globular. It's a knot of about 100,000 stars, re-



solvable in a six inch telescope under good conditions; with binoculars, it's a fuzzy ball. M-22 is one of the biggest and brightest globulars in this part of the sky, but if you use a chart you can easily find many more including M-54, M-55, M-69, M-70 and M-28, along with lots of NGC objects.

Skipping over to Scorpius, let's start at the obvious place — the red giant star Antares. Another globular cluster, M-4, found 1-1/2 degrees to the west, is bright and easily resolved in a six inch scope. About midway between M-4 and Antares, and a bit to the north, is the much more difficult globular NGC-6144. You shouldn't have any trouble seeing it with a three inch or larger aperture if sky conditions are good. North of Scorpius, spread through the dark expanses of Ophiuchus and Serpens, are quite a few globular clusters, including bright ones like M-5 and many smaller, fainter ones. But here we're getting farther from the Milky Way.

As you return from Scorpius toward the plane of the galaxy, you'll notice a complex, patchy area far too complicated to describe accurately. This area of stars and starless patches is marked by dark nebulae of astounding complexity. Long dark lanes run from the area near Antares across about 15 degrees of sky into northern Sagittarius. This dust complex is not far from Earth (as galactic distances go). It spreads along the inner edge of the sun's spiral arm, seemingly stretched along the direction of galactic rotation. Whether it really does so or not, it certainly looks that way.

Binoculars will bring you close to the Milky Way, but without color. Human eyes are insensitive to color at the faint light levels typical of Milky Way objects — such as this view of M-8 (the Lagoon nebula) and parts of the nearby Sagittarius Starcloud (lower left). Visually, the nebula has a slight tinge of green, the brighter stars gleam with a touch of bluish color, and the starclouds with a colorless pale glimmer. Photograph by David Healy.

Just about 10 degrees north, along the galactic plane from the Great Sagittarius Starcloud, is the Lesser, or Small, Sagittarius Starcloud. The open cluster M-24 is embedded in this cloud so that the cluster is hard to see against the starry background. On photographs, the Lesser Starcloud sometimes looks like a wide mouthed beast wearing dark glasses; hence it is also called the Goggle-eyed Monster (so much for nomenclature!). Four degrees to the east is the brilliant open cluster M-25. Although it doesn't have many stars, those it does contain are quite bright. Six degrees west is another open cluster, M-23. This much "smoother" cluster holds several hundred fairly bright stars. Then two degrees north is yet another open cluster, M-18 — a straggler with few bright stars. Direct your sight another degree north, and you'll be looking at M-17, an open cluster bathed in nebulosity. This entire complex is called the Omega nebula. The nebula itself is a H-II region glowing primarily in the red light of hydrogen.

Another three degrees north is an open cluster with nebulosity: M-16, also known as the Eagle nebula. Both M-16 and M-17 are beautiful, softly glowing objects with sprinklings of stars in a six or eight inch telescope.

The fields we've crossed are filled with many more nebulae and clusters than mentioned. You can scan binoculars up and down this area and watch them go by. And it's hardly possible to point a richest field telescope (or even a six inch at 40 power) at these areas of the Milky Way without having *something* interesting in the field.

When we look toward the center of the galaxy, lots of obscuring dust in our own spiral arm blocks the view in several places; but where that dust is thin, we can see right across a gap to the next spiral arm inward from ours. M-8, M-20, M-16 and M-17, for instance, all lie in that spiral arm (called the Sagittarius arm), while our sun lies in the Cygnus arm. As we look toward Cygnus (at right angles to the center of the galaxy), we're looking down the length of our own arm at objects that generally lie closer to us. Just a quick visual scan of the Milky Way in Sagittarius compared to the Cygnus section will convince you that something is rather dramatically different. Where Sagittarius is complex, Cygnus is simple; where Sagittarius is full of incredible numbers of very faint stars, Cygnus has many more bright stars, and generally a smoother appearance.

The overwhelming naked eye feature that extends all the way from Scutum and Serpens Cauda up to Deneb in Cygnus is the Great Rift. Lying very close to the galactic plane, the Rift is a huge lane of dust obscuring everything lying beyond it. We see this remarkable dark cloud of dust against the starclouds of the galaxy that silhouette it on either side. Its length is nearly 1/6 of a full circle, spanning 60 degrees of sky. But in spite of its darkness, the Great Rift is brighter than the sky well away from the band of the Milky Way — an effect due mainly to the rich layer of stars between us and this dust band.

Near the southern end of the Rift, close to the galactic plane, is a glorious starcloud called "the gem of the Milky Way" by E.E. Barnard, pioneering photographer of the Milky Way. The Scutum Starcloud is brilliant, though not as bright as the Great Sagittarius Starcloud. But northern observers have a better view of it because it is higher in their sky. Tucked away along the starcloud's northern edge is the impressively dense open cluster, M-11. Small telescopes can barely resolve this cluster, but a six or eight inch reveals hundreds upon hundreds of stars crowded into a tight little ball. On the southern edge of the Scutum Starcloud nestles another small cluster, M-26. It isn't nearly as rich as M-11, but is still an easy mark for binoculars.

Moving north across the Great Rift, you'll find several more large clusters in Aquila and Serpens embedded in a branch of the Milky Way that pushes out into the dark expanse of Ophiuchus. NGC-4756 and NGC-6709 are both easy to spot in a small telescope; the former sprawls across a full degree of sky.

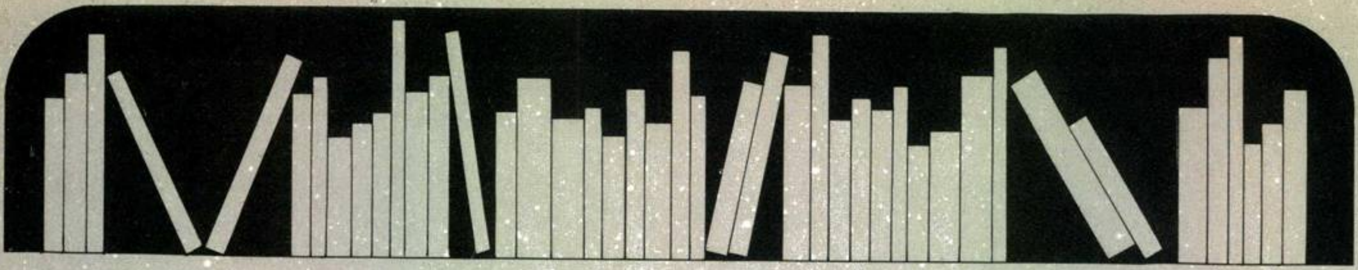
As you follow the Great Rift north toward Cygnus, you'll pass some dense dark nebulae when you reach the declination of Altair, the bright star in Aquila. Dark nebulae, however, are hard to see; even the slightest bit of moonlight or nearby townlight will blot them out. The Rift may have a side branch here because the western lobe of the Milky Way is missing entirely in Vulpecula, presumably obscured by the omnipresent dustlanes that lie along this stellar band.

But as we enter the constellation Cygnus, we encounter a stunning revival: the Cygnus Starcloud, a rich oval nearly 20 degrees long and six degrees wide! Here is one of the most fabulous fields in the sky for an RFT; at 20 power in a six inch RFT, this cloud can only be called mind boggling. The various overlayers of brilliant young blue stars are *stellar associations* — young star groups recently born and shining brilliantly against the deeper, uniform background of faint stars too numerous to count. On color photographs of this area, you can easily see this concentration of hot blue stars. Toward the northern end of the starcloud, near Gamma Cygni, you may also detect faint wisps of nebulosity.

Hop over the Rift to the less spectacular eastern branch a bit south of Epsilon Cygni, and find the star 52 Cygni. Careful scrutiny of this field with a six inch scope reveals the western arc of the Cygnus loop nebula. This supernova remnant is a faint wisp of nebula a degree long. More care is needed to see the other half of this loop of gas because there's no guide star. A few degrees south, you can see NGC-6940 — a small oval cluster of stars.

The main thrust of the Great Rift is toward Deneb, but it turns suddenly to the west, and a starry region lies in your path. The North America nebula (NGC-7000) lies in this region. The nebula itself is very hard to separate from the rich stellar underlayer which follows the same outlines. In an RFT you can certainly spot the nebula if the sky is clear and very dark, and many people can see the nebula in large binoculars. With your eye, you'll see the stellar background, but probably not the nebula itself. A few degrees farther long the Milky Way is the cluster M-39, composed of a very few bright stars. It's a good sight in binoculars, but is lost in most telescopic views of the area.

With M-39, we'll end our tour of the summer Milky Way. Have we omitted any objects? Absolutely! The fields are so rich, and so many smaller, dimmer, and more subtle structures of dust, gas and stars lie waiting to be seen that the job can never be finished. Come back for another look — for many more looks — and don't forget to bring your camera next time!



ASTRONOMY REVIEWS

New Horizons

by NASA

42 pages, paperback, $2.00*
U.S. Government Printing Office

This latest NASA pamphlet is reminiscent of the colorful "Report to Stockholders" booklets which corporations distribute annually to prove that they are good investments. All taxpayers are stockholders in the United States space program; any who read this report will become convinced that NASA is a good investment.

With more than 50 color photos (many of them full page), the pamphlet describes the many varied activities of NASA in 1974-75. Flights to the planets, development of the Space Shuttle, plans for Viking on Mars, and other current topics are all discussed. A six page summary of the Skylab space station project is also included.

Early in the report the authors make the paradoxical claim that, "The greatest discovery of the space age is the planet Earth." Page after page of new discoveries about our land, our water, our air, and the ecosphere in general prove out this assertion. Studies of the Venusian and Martian atmospheres have improved the understanding of the complex weather patterns on Earth. Examining planets in different stages of geological development has given new insights into terrestrial geology. There are other things about Earth which can best be observed (or only observed) from space.

The extent of international space cooperation is hard to appreciate, even after the Apollo/Soyuz flight last summer. For example, five out of six scientific satellites launched by NASA in 1974 were built by other countries: Italy, Holland, England, Spain and Germany. NASA also wants to remind Americans about its research on aeronautics (new airplane wings and engines) and energy (pollution-free power, new auto engines and vehicle streamlining).

No deep insights are offered, but an excellent overall view is presented. This is obviously one sided, but it is a side that is not heard often enough. General audiences who want to know what they are buying in space, and younger readers who like beautiful pictures and simple prose, will all enjoy this pamphlet. *James E. Oberg.*

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Space Rescue and Safety

edited by PHILIP H. BOLGER

272 pages, hardcover, $20.00
American Astronautical Society (1975)

Potential space rescuers have been forced to watch helplessly as space crews perished or limped home from beyond the reach of direct Earth aid. A recent congress of the International Astronautical Federation was the setting for a special meeting of concerned would-be rescuers who discussed the difficult problems of space rescue in the age of the Space Shuttle. Someday the lives of endangered astronauts or cosmonauts may be saved by outside help, as in the science fiction movie "Marooned". So far, however, it's all talk — and this book reports on it all.

This collection of articles represents an enormous spectrum of interests. One gets the first impression that the meeting organizer really had to stretch the scope of the subsession in order to get enough papers submitted. They include engineering proposals, operational constraints, statistical summaries, historical analyses, bibliographical and related subject guides, and reports on present and planned systems.

Two papers deal with emergency one-man "bailout" from orbit. A stranded spaceman must return to Earth without a spacecraft which has become disabled. Inflatable heat shields are proposed, while one engineer suggests a revolutionary (but entirely feasible) heat resistent parachute for return from orbit without any ablative heat shield at all.

Other authors discuss ways to prevent spacecraft failure: reliability, testing, and preflight verification. An interesting survey of spacecraft and engine structural failures (so far, all on the ground) sheds new light on engineering and management techniques which have made the United States space program so successful.

Another excellent section deals with rescue capabilities of the Space Shuttle, including crew training, spacesuits and airlocks. Passengers may be evacuated in pressurized "rescue pods" carried by space-suited astronauts or by the amazing mechanical arm which will be installed on the Shuttle. A "manned maneuvering unit" can provide mobility and carrying power during rescue. All these excellent plans, however, call for the availability of a second Space Shuttle to come to the aid of the disabled sister ship. But the first production space plane may fly solo for more than 1-1/2 years before the next one is ready for flight. Hence, no rescue option will be available during this interval.

But astronauts have lived with that risk, and have survived before. A historical in-depth analysis of the Skylab reliability and rescue programs gives perspective to the problem and reveals why the danger of a "solo" Space Shuttle is very low after all.

Two studies discuss the probability of collision of two orbiting satellites (low, but becoming significant as flights are longer, ships are bigger, and more junk is left in space) and the probability that a downed space crew at sea might be able to depend on world fishing fleets for emergency pickup. Both topics are interesting and important, though too long and somewhat tedious.

The overall level of these papers reflects the general survey nature of the conference; there is just not much deep technical information available. By the end of the book, though, what appeared to be a hodgepodge of disparate topics seems to merge into one "big picture" of space rescue, testifying to the real care with which the session was organized. Space rescue and safety is truly a multifaceted problem.

The result is a fascinating, wide-ranging and easy to read survey of a "life or death" subject.

No American astronaut has ever died in space, and none have died on duty in nearly a decade. The technology and plans described in this book will hopefully continue the trend for many years to come. *James E. Oberg.*

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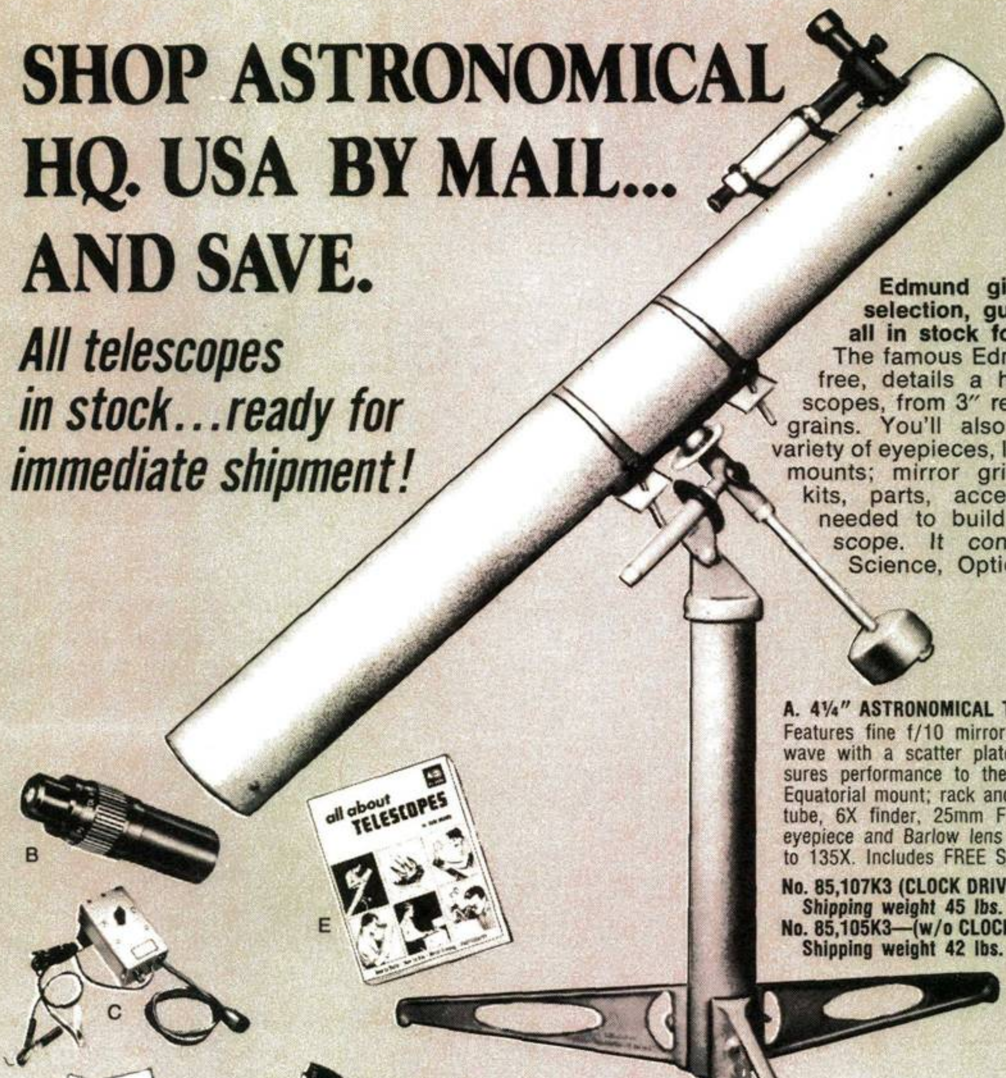

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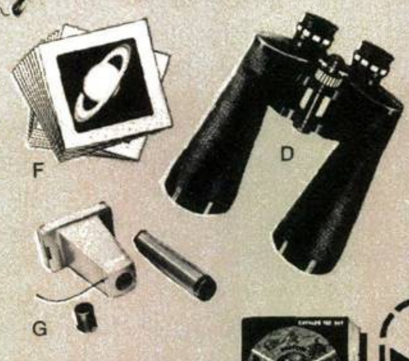

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Moon Subdues Perseid Meteors

Because the Perseids — the finest of all meteor showers — reach their maximum on Aug. 12, this month is generally considered the prime time for meteor observation. Unhappily, this will not be the case in 1976, because of the presence during early morning hours of the waning gibbous moon. Observers might be able to assuage their disappointment somewhat with a look at Jupiter, once more in an excellent position for viewing.

AUGUST SATELLITES OF JUPITER
3:00 a.m. EDT, 12:00 p.m. PDT

1	42301	• • •● •	16	10324	• ●•••
2	41023	• •● ••	17	40213	•● •• •
3	40213	• ●•• •	18	42103	• • • ● •
4	42103	• • •● •	19	42031	• •●• •
5	401	• ●•	20	43102	• • • •● •
6	43012	• • ●• •	21	430	• • ●
7	34210	•• ••●	22	43201	• •• ●•
8	23401	• ••●•	23	41032	• •●••
9	10423	• ●•••	24	40123	• ● •• •
10	02143	●•• •	25	21403	•• •● •
11	21034	• • ● • •	26	20314	• ●•• •
12	014	●• •	27	31024	• •● • •
13	31024	• •● • •	28	3014	• ●• •
14	31204	• ••● •	29	32014	•• ●• •
15	23014	•• ● • •	30	1024	•●• •
			31	01234	● • • • •

The four major satellites of Jupiter orbit the giant planet in periods ranging from just under 2 days to 17 days. They can be seen to change position from night to night. Sometimes their motions become evident after only a few minutes' observation. Only a small telescope is required to detect all four of the satellites and several can frequently be seen in rigidly held binoculars. This table shows the approximate positions of the moons at about 3 a.m. (EDT) on the evenings indicated. First column on the left shows the date. Second column of numbers identifies the moons and their positions relative to Jupiter's disk. (1=Io; 2=Europa; 3=Ganymede; 4=Callisto, and 0= Jupiter's disk.) The third column approximates a telescopic view of the satellites' positions. The orientation of the satellites is shown inverted as seen in a standard astronomical telescope.

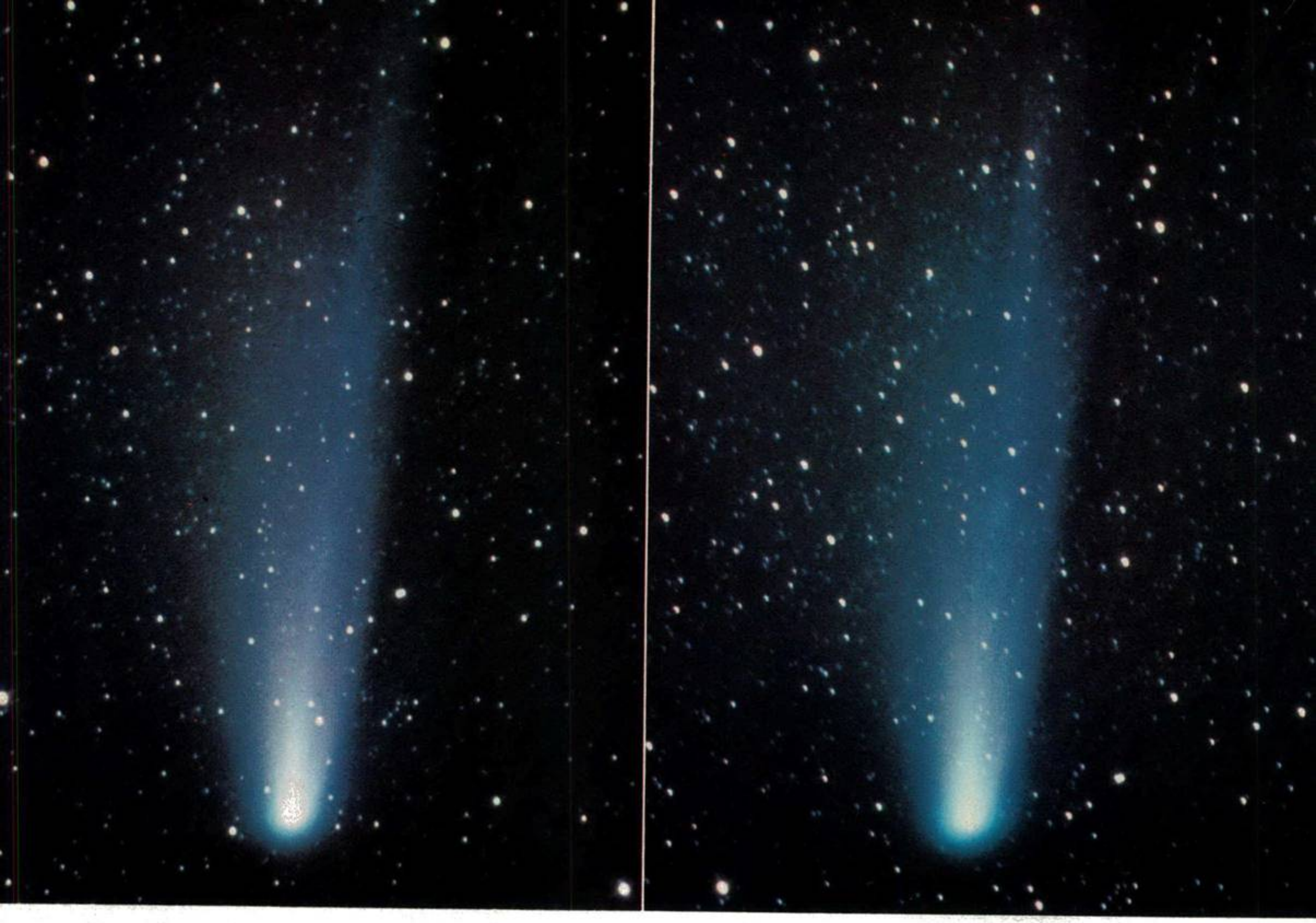
Perseid Meteors

In years when skies are dark and moonless, the Perseids lay justifiable claim to the title of "year's best meteor shower". Beginning toward the end of July and extending through most of August, the shower peaks on the night of Aug. 12-13, when 50 or more meteors per hour can be seen streaking from their radiant in the constellation Perseus.

This year, however, the moon reaches full phase on Aug. 9 and will be in the sky the entire night. All through the predawn hours (the best time for observing meteors) of subsequent nights, the moon will be shining brightly in the sky, blotting out all but the brightest Perseids. You should expect to see only those that reach second magnitude or brighter; the rest will be washed out in the glow from the moon. The Perseids may, therefore, yield this year's top prize to the Orionids, which will reach maximum in October just before new moon.

Nevertheless, it may be worthwhile to attempt some observation of the shower precisely because only the brightest members will be conspicuous. The chance to see bright, reliable meteors should not be passed up. Photographs of individual Perseids — black and white or color — will, of course, be welcome at ASTRONOMY.

M-17, variously known as the Horseshoe, Swan, Checkmark, or (most often) the Omega nebula, is one of the grandest sights available to telescopic observers of the summer Milky Way. Its brightest, rectangular portion has a mass about 800 times that of our sun, and more than 35 stars are embedded in the nebula. This photo, obtained with a cold camera designed by the photographer, is a 17.5 minute exposure on High Speed Ektachrome, through a 12.5 inch reflector at f/4.5. Photograph by Greg Griffith.



These two photos of comet West (above), taken one day apart, demonstrate the changes in the comet's position and in tail structure that took place in a short space of time. At left, one bright streamer extends back from the nucleus in a photo taken on March 27. The next day (right), the streamer has shifted slightly toward the right as the comet itself has moved against the background of stars. In both pictures, the comet is located in the constellation Delphinus. A home built six inch reflector at f/6 was used for each of these 20 minute exposures on GAF 200 film. Photographs by Brad Wallis. Opposite: Innumerable clusters, nebulae and rich star fields are found along the Milky Way in summer; four are pictured here. All four photographs were obtained with cold cameras designed by the photographer. Upper left: The globular cluster M-22 in Sagittarius is one of the brightest members of its class, located in a rich section of the Milky Way. The first globular cluster to be discovered, it is fairly loose and easily resolved with apertures of six inches or more. This 16 minute exposure on High Speed Ektachrome was made through a 12.5 inch Newtonian at f/4.5. Upper right: Some of the widespread nebulosity around the star Gamma Cygni is seen here. Invisible to the naked eye, the nebula is prominent in long exposure photographs and spreads over a large area. An eight inch reflector at f/4 was used for this 40 minute exposure on GAF 500. Lower left: A tiny shred of nebulosity is NGC-6888, sometimes called the "Dividing Cell" nebula. The wisp of gas, seldom photographed, lies in Cygnus, close to the main concentration of the Gamma Cygni nebulosity. This is a 40 minute exposure on GAF 500, obtained through an eight inch reflector at f/4. Lower right: Photographs of M-16 reveal a widespread nebula with several dark lanes, in which is embedded a cluster of red stars. Like the Lagoon nebula farther south, M-16 is a stellar birthplace. A faint resemblance to a bird with outstretched wings has given the object the name of "Eagle nebula"; it is located near the southern border of Serpens Cauda. A 17.5 minute exposure on High Speed Ektachrome was made with a 12.5 inch Newtonian at f/4.5. Photographs by Greg Griffith.

Comet d'Arrest

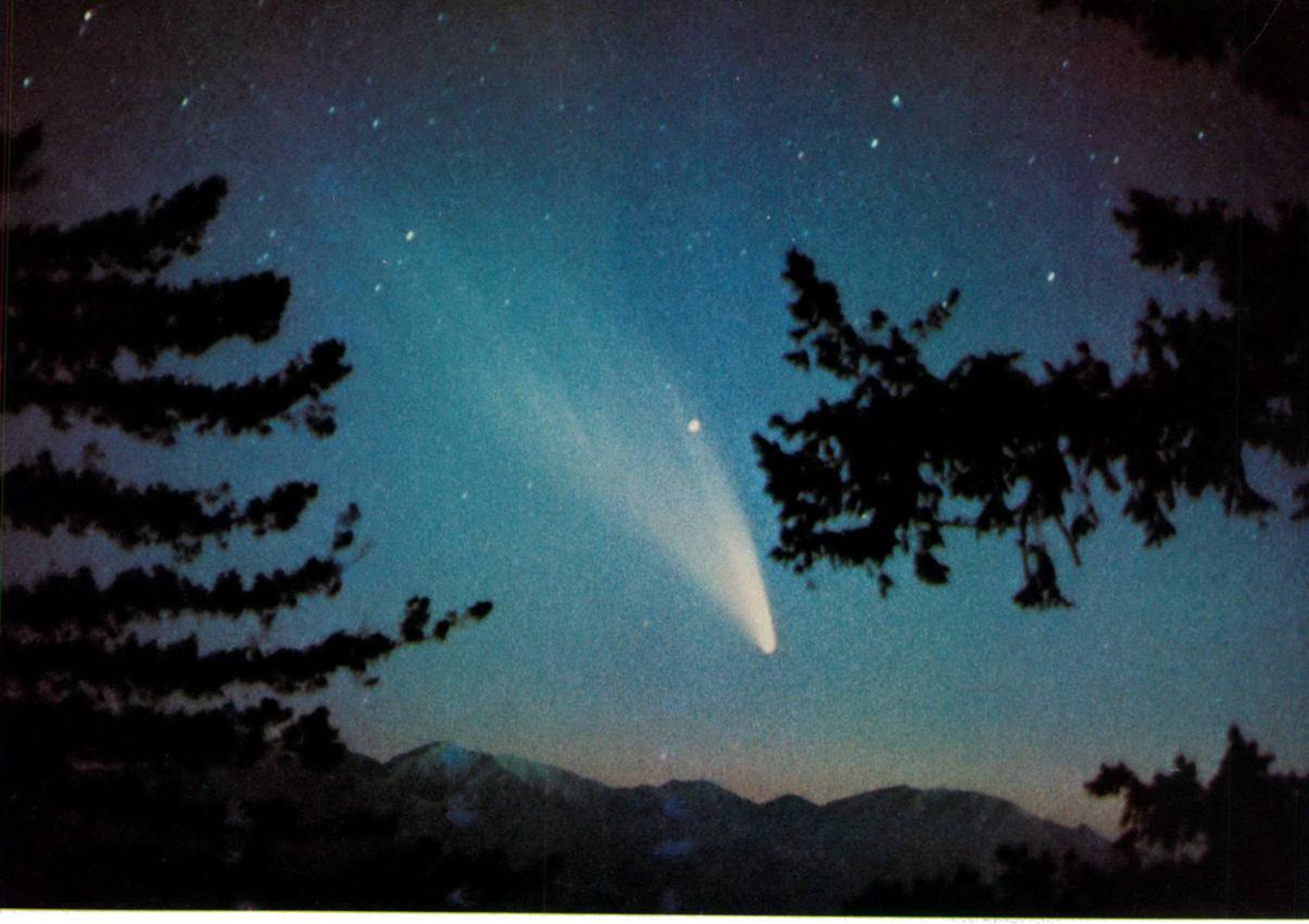
For those unfortunates — and they must be few in number — who missed comet West in March and April 1976, the close passage by comet d'Arrest of Earth this month will provide another chance at comet observation. The comet will be making its most favorable appearance in our skies since its 1851 discovery.

This does not mean, however, that comet d'Arrest will put on anywhere near as spectacular a show as West provided; at best, d'Arrest will be about sixth magnitude, visible in richest field telescopes, small telescopes, or (if you're lucky) binoculars. Its nearest approach to Earth will take it to

Predicted Positions for Comet D'Arrest

Date	R.A.	Dec.	Mag.
Aug. 5	20^h49^m	+1°53'	6.7
10	21^h20^m	-6°24'	6.4
15	21^h54^m	-15°16'	6.5
20	22^h29^m	-23°24'	6.7
25	23^h02^m	-29°53'	6.9
30	23^h32^m	-34°31'	7.1
Sept. 4	23^h56^m	-37°32'	7.4
9	0^h16^m	-39°21'	7.8

Predicted magnitudes are approximate.



One of the most spectacular comets of the 20th century, comet West was even more grand in photographs. It rises through the trees and above the mountains in this picture made from Mount Wilson Observatory on March 4. The magnitude of the nucleus was about +1, and the huge dust tail spread across 15 degrees of the sky. This unguided 35 second exposure was made on High Speed Ektachrome through a 55mm lens at f/1.4. Photograph by Arthur L. Lane.

within about 14 million miles (about half the closest Earth-Venus distance). The comet will reach perihelion on Aug. 12.

Comet d'Arrest is a *periodic* comet: Its orbit has been accurately calculated and it returns to the vicinity of the sun on a regular schedule — every 6.2 years. Watch for it as it moves southeast through the constellations Delphinus, Aquarius and Sculptor. By early September, it will be fading and close to the horizon for United States observers. The comet's predicted positions are given in the accompanying table.

Satellite Shadows on Jupiter

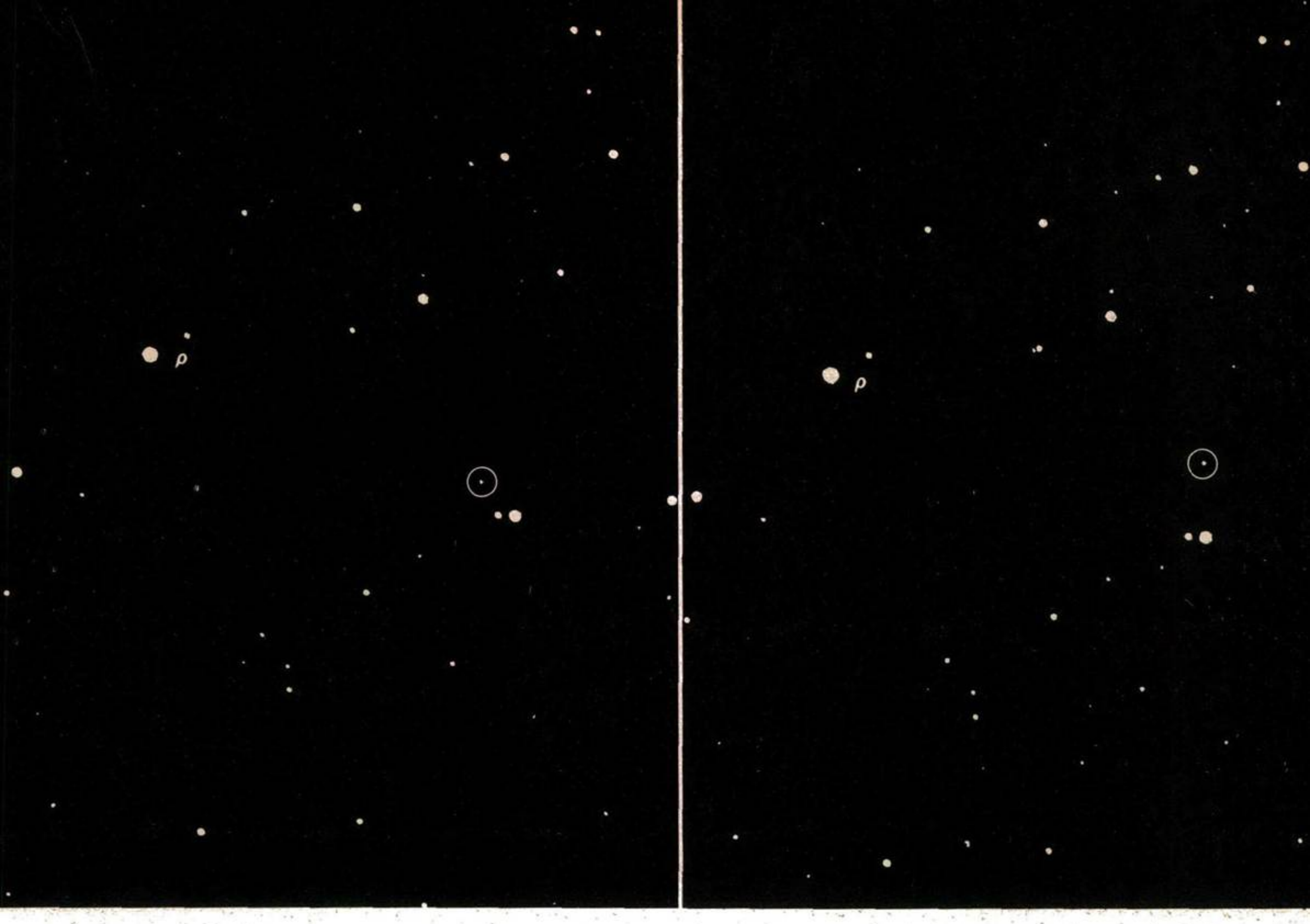
Date	Satellite	Transit Begins (EDT)	Transit Ends (EDT)
Aug. 3	2	4:50 a.m.	7:24 a.m.
5	1	2:30 a.m.	4:37 a.m.
12	1	4:23 a.m.	6:31 a.m.
13-14	1	10:52 p.m.	12:59 a.m.
19	3	2:21 a.m.	4:29 a.m.
19	1	6:17 a.m.	8:24 a.m.
20-21	2	11:22 p.m.	1:56 a.m.
21	1	12:45 a.m.	2:53 a.m.
26	3	6:22 a.m.	8:30 a.m.
28	2	1:59 a.m.	4:33 a.m.
28	1	2:39 a.m.	4:46 a.m.

1 =Io
2 =Europa
3 =Ganymede
4 =Callisto

Jupiter

Located in the constellation Taurus, the largest planet rises shortly before midnight during most of August. Its diameter increases from 35.2 to 38.5 seconds of arc, while its distance from Earth changes from 485 million miles on Aug. 1 to 443 million miles by month's end.

For any observer, beginning or experienced, Jupiter's moons rank among the most fascinating phenomena of any in the sky. One reason for this is that the line-up of satellites changes from night to night, giving telescopic observers an excellent chance to actually watch astronomy in motion. In addition to the motion of four major moons, an added attraction is provided by the satellites' shadows which frequently cross the Jovian disk. The combination of a satellite's motion and Jupiter's own rotation will show the shadow creeping across the cloud bands. This month ASTRONOMY resumes its "Satellites



The asteroid Juno reached opposition on March 1 in the constellation Leo; the two photographs above, taken a month later, show the motion of the minor planet across the sky. Both are 10 minute exposures made through a 200mm lens at f/4.5. The picture at left was taken on April 2, while the one at right dates from April 4. These are black and white negative prints made from the original exposures on GAF 500 slide film. Photographs by Diane L. Payton.

of Jupiter" and "Satellite Shadows" charts, both of which can be found in Sky Almanac.

Jupiter will shine near magnitude -2 throughout August. Watch Jupiter and the last quarter moon on the night of Aug. 17-18; the moon will slowly creep up on the planet, and the two will be separated by only one degree of arc at 5 a.m. EDT. Those watching the event from southern South America will see an occultation.

Mercury

The difficulties inherent in seeing Mercury are well-known to potential observers, many of whom have probably failed to glimpse the little planet even when conditions seemed excellent. The situation is not helped by circumstances such as those that prevail this month, when Mercury, despite its being at greatest eastern elongation on the 26th, will remain beyond the reach of all but the most efficient planet watchers. Because the ecliptic is very low above the western horizon in August, Mercury does not stand high enough to be easily glimpsed; it can easily be blotted out by horizon haze or obscuring trees or buildings. A much better opportunity for observing Mercury will come at October's greatest western elongation.

Venus

During August, Venus won't get much higher above the horizon than Mercury will — only about eight degrees. Setting within an hour of the sun, Venus should be easier to see than its tiny inner neighbor, since its magnitude is -3.3. For the rest of this year, the planet will remain an evening star, slowly brightening and gradually becoming more dominant in the western sky.

Mars

Observation of the red planet in 1976 has effectively ended, for Mars is now so faint (magnitude +1.9) and low in the west at sunset that it is hard to spot. Its distance from Earth increases from 218 to 228 million miles; the planet moves from Leo to Virgo on Aug. 12. Lack of a prominent guide star will make identification difficult for those who are unsure of their constellations. Mars' visual appearance is, in fact, in direct inverse proportion to the interest evoked by the Viking mission to that planet.

Saturn

Too close to the sun to be observed for most of the month, Saturn might be glimpsed by determined observers during the last mornings of August when, located in Cancer, it rises shortly before the sun.

PHOTOGRAPHY IN ASTRONOMY

Red Light Sky Photography

by

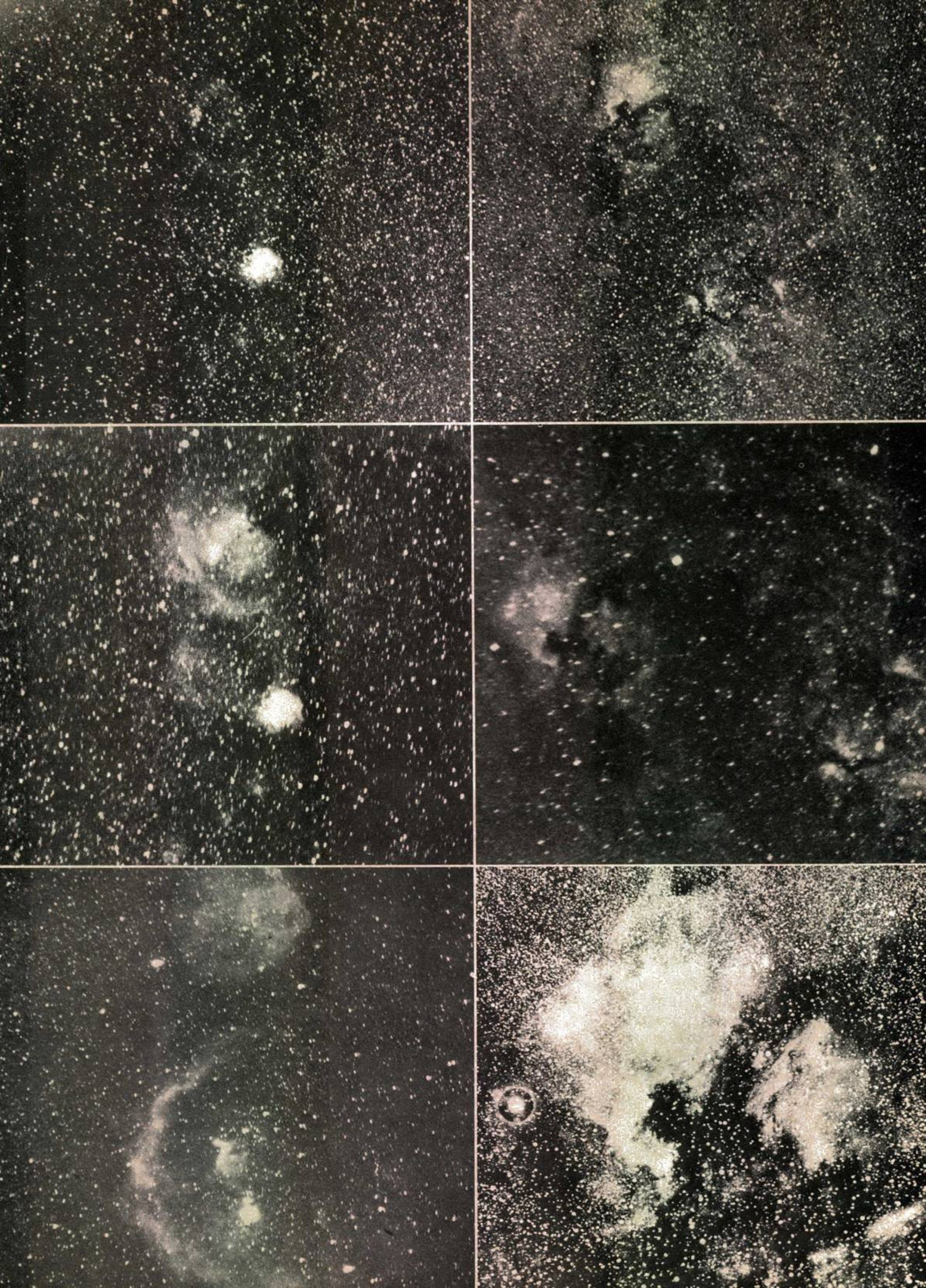
John Davis, William Tobin and Joel Eaton

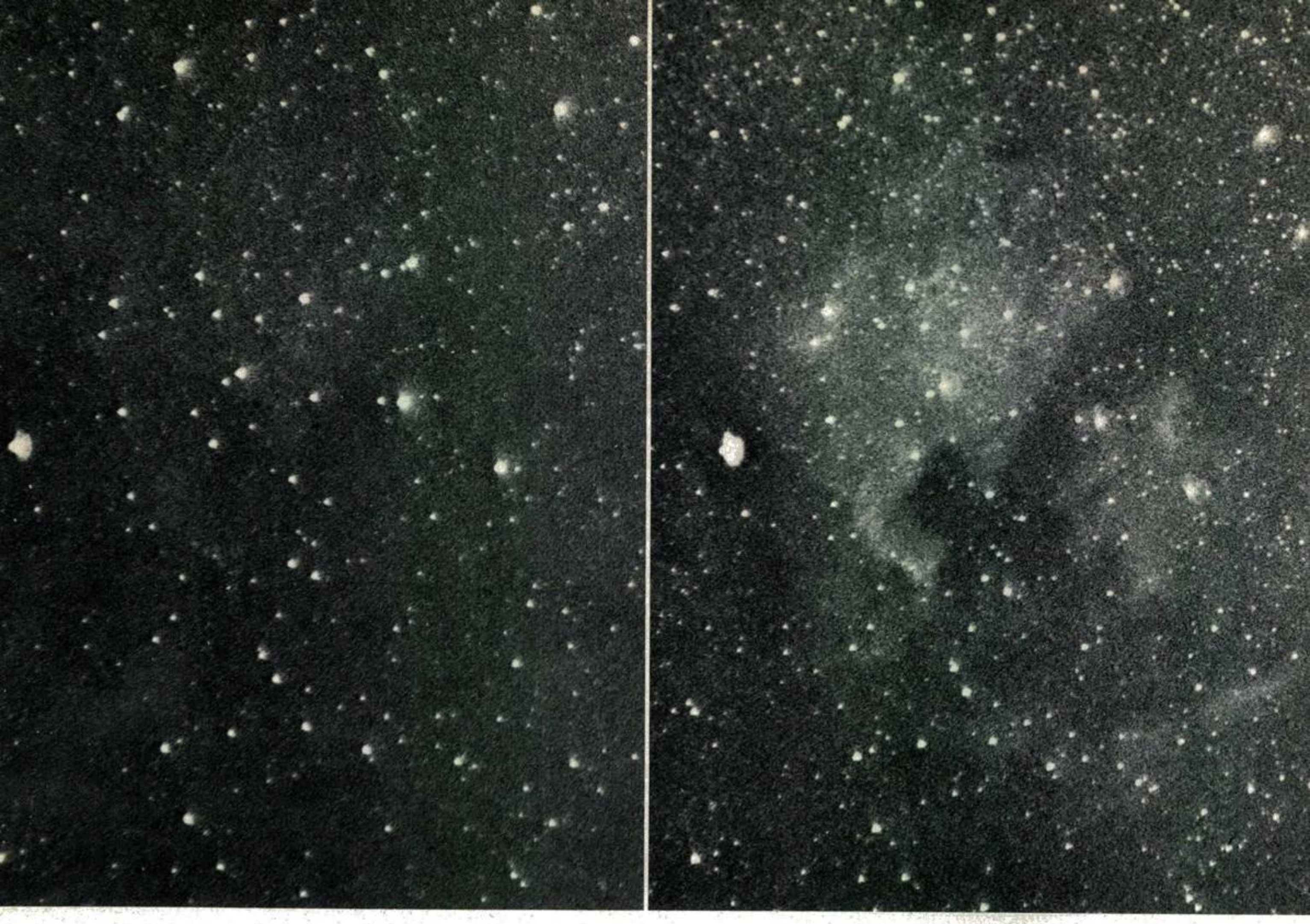
When a massive star forms, not only does it shine with the light of 10,000 suns, but it also lights up the surrounding gas. These glowing clouds of gas are called *gaseous nebulae.* Stars shine at all wavelengths, but these nebulae are more particular as they radiate most of their energy at only a few special places in the spectrum. With cheap and simple equipment, the astrophotographer can capture these faint glowing clouds of gas by viewing them in their special wavelengths. Many of these nebulae cover several degrees of sky — thus they'll look impressive in the field-of-view of an ordinary 35mm camera. Besides a camera, all that is needed to photograph these objects is a clock driven mount, the proper filter and some special film.

The best wavelength for photographing these nebulae is that of the *Hydrogen-alpha (H-alpha) emission line* at 656 nanometers wavelength. Light at 656nm is deep red — deeper than ordinary film will record. (Ordinary film stops working before the eye stops seeing to prevent the lips and noses from coming out too light on snapshots.) Special film is required for deep sky nebular photography, and the most useful is Kodak 103aE. It is good for two reasons: 1) the basic emulsion (type 103) has been treated to make it sensitive to some red wavelengths — which is what the *E* stands for, and 2) 103aE film has been treated to suppress reciprocity failure — which is what the *a* means. Also suitable is 103aF film, though it's not as good because it is sensitive too far into the red.

How can a film be *too* sensitive? In nebular photography, you want to capture objects which emit a very peculiar spectrum with light mainly in one narrow line. But most of the sources of contaminating background light emit over a wide part of the spectrum. If we can select a narrow "window" in the spectrum, using a filter and film properly chosen to make that window as narrow as possible, we can record more of

Top left: The nebulosities NGC-2237 (the Rosette) and NGC-2264 were captured in one hour at f/2.8 on hypersensitized 103aE, using a Wratten #92 filter to isolate the H-alpha line. At center left is a simultaneous 90 minute exposure at f/1.8 on hypersensitized 103aE film. Here, an interference filter passing only six nanometers around H-alpha was used. Note that NGC-2264, hardly visible in the top picture, is now strongly recorded, but fewer stars are visible. Photographs by John Davis and William Tobin. At bottom left is the Orion region in H-alpha showing the Lambda Orionis nebula and Barnard's loop. The 100 minute exposure on 103aE film was shot at f/1.8 with a 35mm camera and an interference filter. Photograph by Joel Eaton. Top right: Using a 50mm lens at f/4, a plexiglass filter similar to a Wratten #29, and 103aE film, NGC-7000 (the North America nebula) and the Gamma Cygni nebulae were captured in a 40 minute exposure. Photograph by Leonard Marek. Center right: The same subject was recorded in a 75 minute exposure on hypersensitized 103aE using a "narrower" Corning #2403 filter glass at f/2.8. Photograph by John Davis and William Tobin. Bottom right is a close-up of the North America and Pelican nebulae. The three hour exposure was made on 103aE with a 24 inch focus Aero-Ektar lens at f/6 and a Wratten #29 filter. Photograph by Clarence Custer.





A proper film-filter combination can cut light pollution greatly. At left is a 75 second unfiltered exposure; on the right, a 360 second exposure through a Wratten #92 filter. 103aE film was used for both shots taken from the heavily built-up area 15 miles east of Manhattan Island (New York City). The lens used was a 135mm f/1.8 telephoto. Photographs by David Healy.

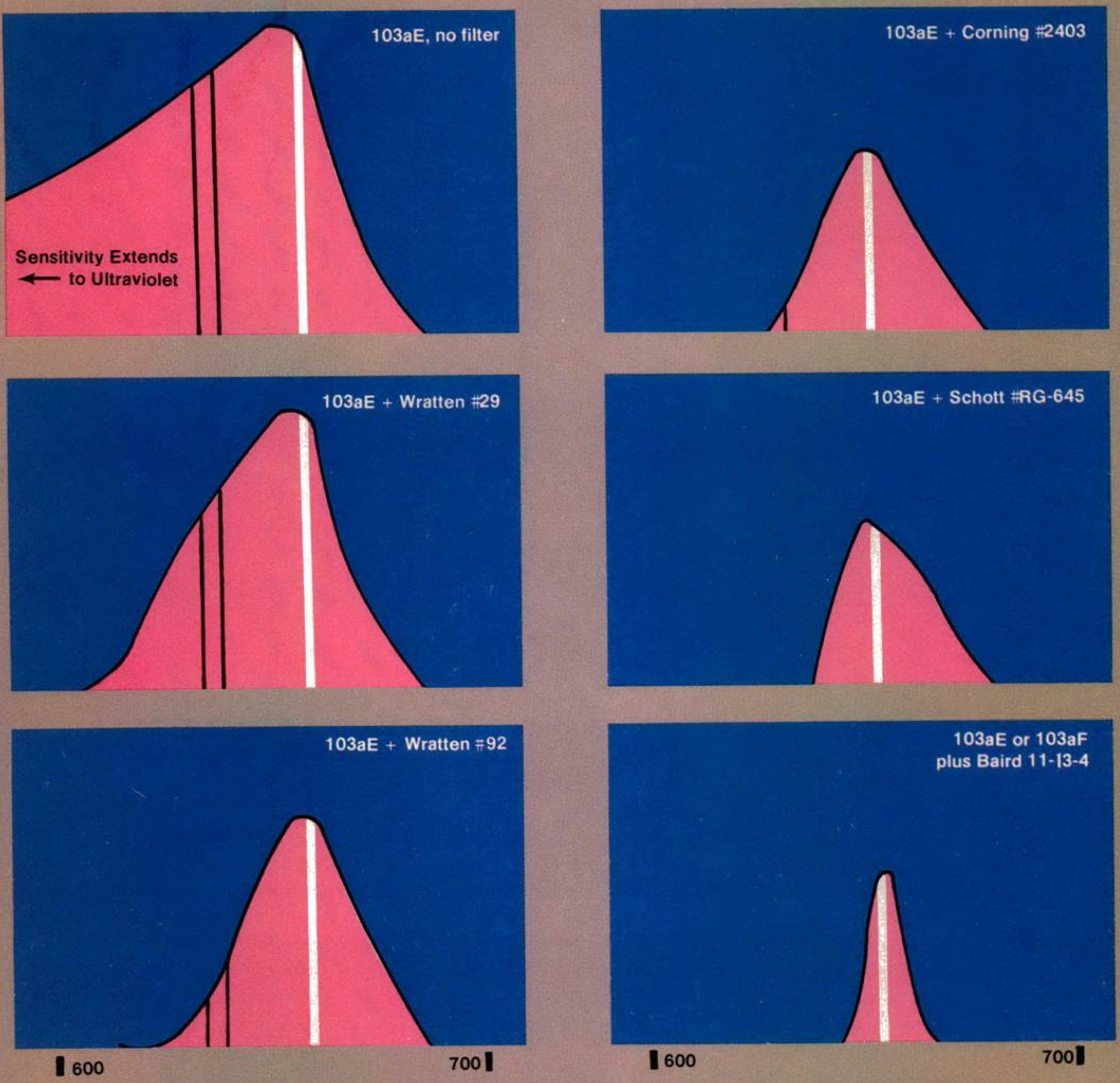
the nebula without recording background light which will fog and destroy the image of the nebula. So, we must choose a filter (called a *short cut* filter) which cuts off all wavelengths shorter than the line we are to record, and we must choose a film that isn't sensitive to wavelengths longer than we want. 103aE was designed to cut off at wavelengths just a bit longer than H-alpha. On the other hand, 103aF was designed to record very deep red light, and in so doing, it records unwanted background light when you photograph the nebulae.

The unwanted background light comes from many sources. Even on the very darkest night the sky has some brightness, called *nightglow*. The light from billions of stars in our galaxy can also wash out the nebulae, most of which lie against the background of the Milky Way. And unfortunately, city light pollution often provides the greatest source of unwanted illumination. A carefully chosen film-filter combination can help — but not eliminate — the effects of city lights. The moon can be a nuisance too, and deep sky astrophotography should be done when the moon is down or close to new.

In choosing your filter, you'll especially want to avoid transmitting the bright oxygen airglow emission lines at 630 and 636nm (part of the nightglow). A filter that is as opaque as possible at 636nm — but as transparent as possible at 656nm — is best. Two kinds of filters are available: glass and gelatin. The best inexpensive filters are made of colored glass; the Corning #2403 and Schott #RG-645 each cost about $10. They begin to transmit light at wavelengths around 640nm, and continue being transparent well into the infrared. In combination with an E film, which cuts off soon after the H-alpha line at 656nm, it is possible to get a peak of sensitivity of the film and filter together that is only 20 to 30nm wide and centered on H-alpha. An F film, with its sensitivity extending farther into the red, gives sensitivity to a wider range of wavelengths.

Starting your experiments in H-alpha photography, a gelatin filter has two advantages: cheapness and availability. A two-inch-square Kodak Wratten filter costs less than $3 and will be available in your photo store, whereas glass filters must be ordered from industrial suppliers. Your best bet in a gelatin filter is the Kodak Wratten #92. Other deep red filters such as a Wratten #29 will work, but not as well because they pass more of the sky background. Gelatin filters are soft; they scratch easily and can be damaged by moisture. With reasonable care, however, they'll give adequate service.

Film + Filter: Window to Nebulae



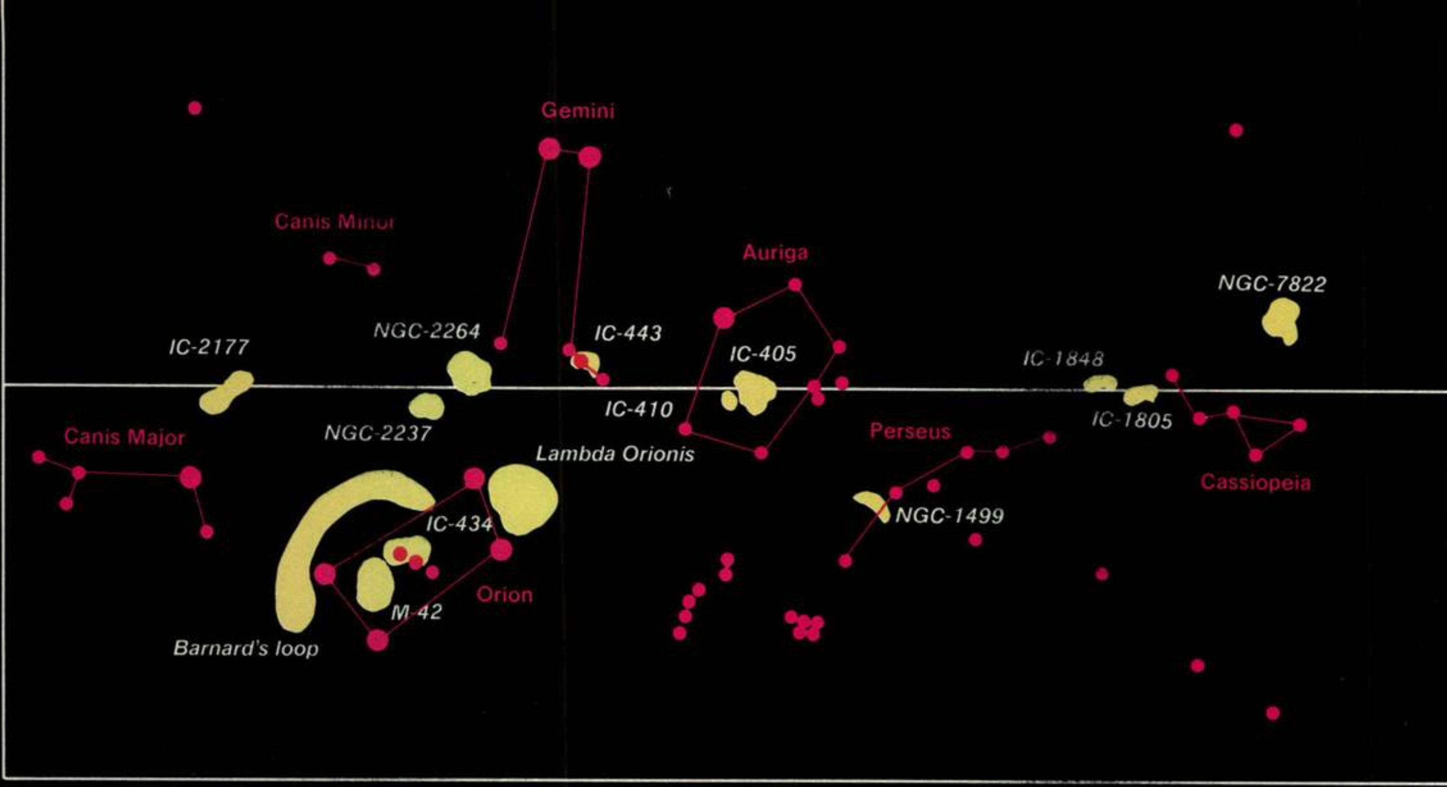
The proper film and filter can record the H-alpha line without recording much unwanted glow from the night sky. The curves above show the width of the film-filter "window": wavelength is shown on the horizontal axis (given in nanometers) and sensitivity on the vertical. The white line indicates the position of the H-alpha line, and the black lines show where the interfering spectral lines from airglow lie. More airglow lines lie between 680 and 700 nanometers; while 103aE is insensitive to them, 103aF is. Diagram by David Schwartz.

*Wratten filters may be ordered through your local photo dealer. Kodak publication B-3 ("Kodak Filters for Scientific and Technical Purposes") may be ordered from Dept. 454, Eastman Kodak Company, Rochester, N.Y. 14650, or obtained through your local photo dealer.

*Corning filter information is available from Robert C. Saxton, Optical Products Dept., Corning Glass Works, Corning, N.Y. 14830. The #2403 filter must be ordered through Corning dealers (names are supplied by Corning), as CS 2-58. A two inch square filter (polished) costs about $10. Corning's catalog can be purchased for $1.

*Schott filters can be ordered from Schott Optical Glass, Inc., Duryea, Pa. 18642. The RG-645 (polished) filter, two inches square and 3mm thick, costs $12.15. (Schott's minimum order is $30.) No catalog is available, but inquiries may be directed to Jim Speicher, Product Manager.

*Baird-Atomic, Inc. 125 Middlesex Turnpike, Bedford, Mass. 01730, is one of many suppliers of interference filters. Their standard filter 11-3-4 (6563A) costs $77 in the two-square-inch size. Better filters are available at higher prices, and their catalog is available on request.



H-II Regions: The Red Nebulae

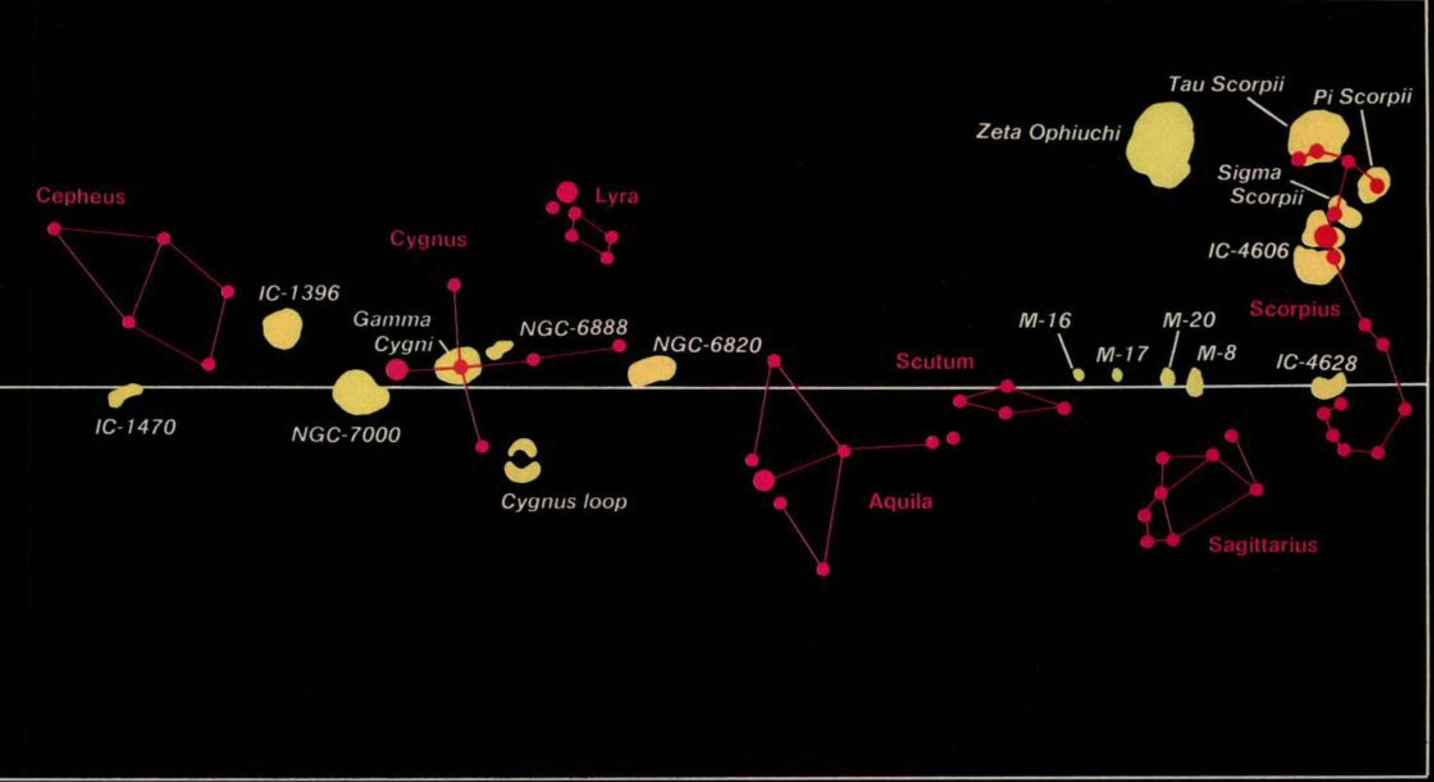
Most gaseous nebulae are glowing clouds of hydrogen gas excited by hot stars. These hot stars are young, bright and blue, and emit copious quantities of ultraviolet light. This ultraviolet light ionizes atoms in the surrounding gas; that is, it violently strips electrons from their parent hydrogen atoms, giving rise to a gas in which electrons and protons move freely about. (Volumes where this has happened are known as H-II regions, or "gasbags".)

The liberated electrons can recombine with the protons to re-form hydrogen atoms; as they do so, they free themselves of excess energy by emitting light. But unlike the ultraviolet light that gave the electrons the energy to break free from their parent atoms, this light from the recombination is at a series of special wavelengths. Astronomers call these wavelengths H-alpha, H-beta, H-gamma, etc. The process of re-emission of light at a different wavelength is called fluorescence, and in many ways a gaseous nebula is similar to a fluorescent light. The H-alpha line is the brightest emission line of gaseous nebulae and accounts for their characteristic red color. However, the nebulae also glow in H-beta at 486nm, with a blue line; if you can find a suitable filter, it should be possible to take H-beta photographs. But because this line is far weaker, much longer exposures would be needed.

Astronomers are interested in H-II regions not only because they make pretty pictures, but because in many cases they are regions in which stars have recently formed. The complexes of nebulosity and young stars associated with the belt and sword of Orion are being studied intensively to learn about the process of star formation.

Other H-II regions are an entirely different kind of object — the expanding remnants of a supernova explosion. Here the energy to ionize the hydrogen debris from the supernova comes from its collision with interstellar gas and dust. Examples of this type of object are the Cygnus loop nebula and IC-443.

The nebulae are distributed in the plane of the Milky Way for the simple reason that the young stars and explosions which illuminate the nebulae are mostly in the plane of the Milky Way. A few nebulae, such as Zeta Ophiuchi, appear to be rather far from the plane, but this is because they are nearby. Young stars are formed mostly in the spiral arms of our galaxy, so it is not surprising that most of the H-II regions are also found in spiral arms; in fact, astronomers have used H-II regions to map the spiral arms near the sun. It appears there are at least three distinct arms in the sun's neighborhood. When you look toward the North America nebula, you are looking along the Cygnus arm which extends past the sun and connects with the stars in Orion. Looking toward the center of the galaxy, you see an arm inside the Cygnus arm — the Sagittarius arm. There also appears to be an arm farther out than the Cygnus arm, called the Perseus arm.


Tau Scorpii
Pi Scorpii
Zeta Ophiuchi
Sigma Scorpii
Cepheus
Lyra
Cygnus
IC-4606
IC-1396
Scorpius
Gamma Cygni
NGC-6888
M-16
M-20
NGC-6820
M-17
M-8
Scutum
IC-4628
IC-1470
NGC-7000
Cygnus loop
Aquila
Sagittarius

H-Alpha Objects For Your Camera

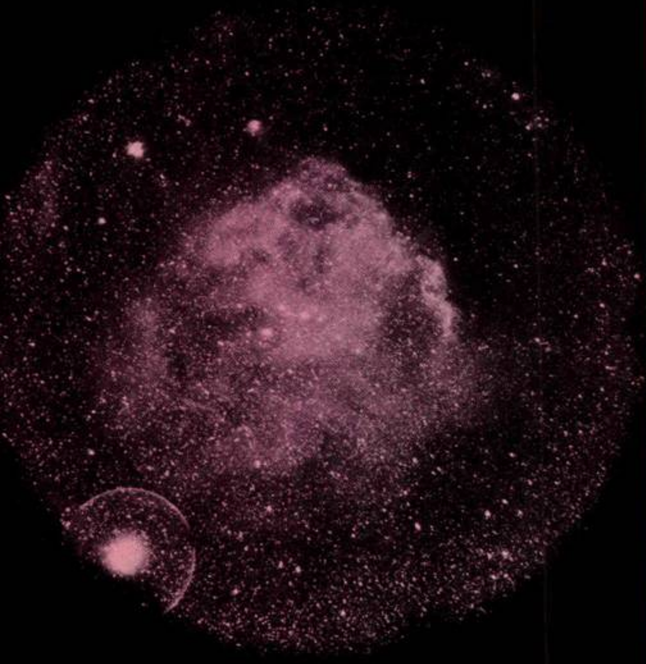
Name	Size	Coordinates	Brightness	Other Names
Barnard's loop	20°	$5^{h}25^{m}$ -4°	faint	
Lambda Orionis	6°	$5^{h}32^{m}$ 9°54'	faint	
NGC-2264	4°	$6^{h}38^{m}$ 9°57'	faint	
NGC-2237	1°	$6^{h}30^{m}$ 4°40'	bright	Rosette nebula
M-42	1°	$5^{h}33^{m}$ -5°25'	bright	Orion nebula
IC-434	1°	$5^{h}39^{m}$ -2°26'	bright	Horsehead nebula
IC-2177	1°	$7^{h}03^{m}$ -10°29'	faint	
NGC-1499	5°	$4^{h}00^{m}$ 36°17'	bright	California nebula
IC-405	1°	$5^{h}13^{m}$ 34°16'	faint	
IC-410	1°	$5^{h}19^{m}$ 33°28'	faint	
IC-443	1°	$6^{h}14^{m}$ 22°48'	bright	
NGC-7822	3°	$0^{h}01^{m}$ 68°27'	faint	
IC-1805	2°	$2^{h}28^{m}$ 61°15'	faint	
IC-1848	2°	$2^{h}47^{m}$ 60°13'	faint	
IC-1470	1°	$23^{h}13^{m}$ 59°30'	faint	
Gamma Cygni	4°	$20^{h}20^{m}$ 40°05'	bright	
NGC-7000	4°	$20^{h}57^{m}$ 44°08'	bright	North America nebula
Cygnus loop	3°	$20^{h}49^{m}$ 30°45'	bright	Veil nebula
IC-1396	3°	$21^{h}38^{m}$ 57°14'	faint	
NGC-6820	40'	$19^{h}40^{m}$ 22°58'	faint	
NGC-6888	20'	$20^{h}11^{m}$ 38°16'	bright	Dividing Cell nebula
M-8	1-1/2°	$18^{h}02^{m}$ -24°20'	bright	Lagoon nebula
M-16	1-1/2°	$18^{h}16^{m}$ -13°48'	bright	Eagle nebula
M-17	1°	$18^{h}18^{m}$ -16°12'	bright	Omega nebula
IC-4628	30'	$16^{h}49^{m}$ -40°18'	bright	
M-20	20'	$17^{h}59^{m}$ -23°02'	bright	Trifid nebula
Zeta Ophiuchi	8°	$16^{h}34^{m}$ -10°28'	faint	
Tau Scorpii	3°	$16^{h}32^{m}$ -28°07'	faint	
Pi Scorpii	3°	$15^{h}56^{m}$ -25°58'	faint	
Sigma Scorpii	1°	$16^{h}18^{m}$ -25°28'	faint	
IC-4606	30'	$16^{h}26^{m}$ -26°20'	faint	

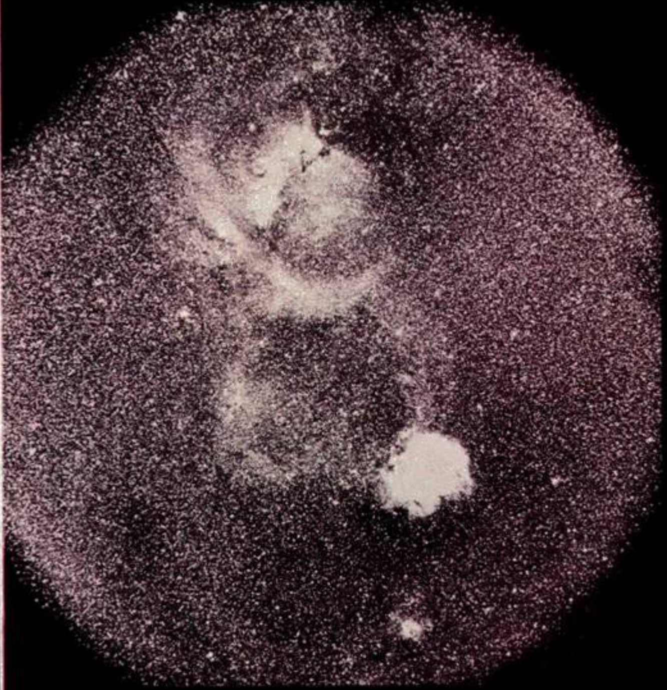
M = Messier Catalog NGC = New General Catalog IC = Index Catalog

103a Films

103a films can be obtained in 36-exposure, 135 cassettes for about $7 from Optica b/ c Company (see ad in ASTRONOMY). These films deteriorate unless refrigerated until needed, so "thaw" the film for about four hours before use. Kodak D-19 developer is recommended by Kodak for 103 emulsions. (Not all camera stores carry D-19, and if necessary you can use the more readily available D-76.) MWP-2 is a "superdeveloper" formulated at Hale Observatories for 103 films. It is available from Clayton Chemical Co., 3867 S. Grandview Blvd., Los Angeles, CA 90066.

103 film comes with a black antihalation backing (called a Rem-Jet backing) which prevents exposure of the light sensitive surface by light reflected from the back side of the film. This backing should dissolve in the developer, though it occasionally doesn't. However, it can easily be removed after the film is half fixed: Rub the back with a cotton swab soaked with developer, rinse in water, and finish the fixing.





Speed Up Your Film — With Water!

Exposure times can be shortened by *hypersensitization* of the film. You can hypersensitize E and F films quite simply by washing them in cold water. A method that works well is to tape the film cassette to a wire suspended well above a table in a dark room. Then pull as much film as you want to hypersensitize from the cassette. A deep glass of cold (about 40 degrees Fahrenheit), dilute Kodak Photoflo solution should be brought up under the film, and the film immersed for about two minutes. Be sure the water is cold — warmer water could dissolve the emulsion off the film. After removing the film from the glass, weight it with a clothespin so it hangs down without curling. Cold air from a hairdryer blown over both sides of the film for about 20 minutes will thoroughly dry it. You can touch the edges and back of the film to see if they are dry, as well as part of the emulsion near the clothespin. Then, wind the film back into the cassette. Suspending the film seems to be the best way of preventing fingerprints on the emulsion.

Hypersensitization will wear off in a few days — unless you want to place the film in the freezer, where it should last for up to five weeks — so hypersensitize only as much film as you'll need for each night's photography.

Your glass or gelatin filter should be mounted in front of the camera lens. Tape and Plasti-tak will work, but it's a good idea to get a gelatin filter mount for your camera. It is important that the filter not rattle about, for if the filter moves during an exposure, double images may result.

A third type of filter — the interference filter — exist; however, those with a range of 5 or 10nm around two inches square may cost $100 or more. Also, several technical difficulties are associated with interference filters. Only light passing perpendicularly through an interference filter is properly filtered; light at all other angles is filtered at a shorter wavelength. This will result in a loss of sensitivity for nebulae at the edge of your camera's field of view. This effect shows on some of the pictures in this article. Some H-alpha interference filters also leak light at shorter wavelengths — enough that they may even look blue! In this case, an extra red filter (which may be difficult to mount properly) is necessary. If you have a Schmidt camera, an interference filter will not work very well because of the camera's fast optics. Considering the cost and other problems involved, don't start with an interference filter. After you've gained experience with glass and gelatin filters, you may feel the added expense is justified.

Gaseous nebulae are very faint, so long exposures are needed. The best exposure depends on the brightness of the nebula and the sky, the f-ratio of the camera, the type of filter and the sensitivity of the film. All these can vary; in particular, film sensitivity varies substantially from one production run to another, so it isn't possible to recommend exact exposures. You'll have to start with a trial exposure and then adjust the time as necessary. Too short a time will not reveal the full extent of the nebulosity, while too long a time will result in sky fogging the exposure completely.

On a dark night away from city lights, with an f/2 or f/2.8 camera lens and any of the recommended filters, your trial exposure should be about one hour. Develop the film after each night's work so you know what alterations to make in the next night's shooting. To help judge what these corrections should be, it is essential to keep a record of the length of each exposure, the filter used, and how bright the sky appeared. In city suburbs, your exposures may fog in only 5 or 10 minutes — but you'll still find you'll record objects you couldn't without the filter.

Of course, there is a tradeoff to be made between exposure times and f-ratios. Low f-ratios allow shorter exposures but suffer more from lens aberrations that deform the star images. For most nebulae, even the shortest exposures necessary are long enough that some method of guiding is needed. You'll need a well-aligned equatorial mount with an accurate drive for guiding hour long exposures. (The problem of accurate guiding was discussed in Photography in Astronomy in January 1975 and June 1976.)

For locating nebulae suitable for H-alpha photography, one of the best resources available is the Skalnate Pleso **Atlas of the Heavens** and its companion catalog. These are publications of the Czechoslovakian Academy of Sciences, but are available in the United States from the Sky Publishing Corporation. In the **Atlas**, emission regions are indicated in green (though unfortunately so are reflection nebulae which emit blue light rather than red). Some of the large, very faint nebulae, such as those associated with the stars Zeta Ophiuchi and Lambda Orionis, are not properly shown in the **Atlas**. However, it does show most of the objects appearing in the list accompanying this article. Norton's **Atlas** is less useful for finding nebulae; the maps use Herschel designations which need to be converted to NGC numbers to be of use, and Norton's is not as complete as the Skalnate Pleso **Atlas**.

Although there is a wealth of nebulae to be photographed, astrophotographers seem to concentrate on the same old ones such as the North America nebula and the Orion. But many other areas deserve as much attention. The nebulosities in Monoceros are good subjects for 35mm work. Although you've seen many pictures showing the nebulosity in Sagittarius, you probably haven't seen any showing the nebulae in Scorpius and around Zeta Ophiuchi. Pictures of Cassiopeia would be rewarding if they showed the nebulosities to the north and east of the constellation.

Although we've been concerned here with wide-angle 35mm work, those with telephoto lenses or Schmidt cameras will find there are many smaller objects that deserve attention. If you like the Cygnus loop, there is a similar object in Gemini: IC-443. Instead of the North America nebula, why not try the nearby IC-1396? The Lambda Orionis nebula would just about fill the field of view of a small Schmidt camera; IC-405 and IC-410 in Auriga would also look good. An interesting subject for Schmidt work is the Dividing Cell nebula (NGC-6888) in Cygnus.

H-alpha photography is comparatively simple and a very successful technique for amateur astrophotographers. The results here, though not perfect, should be encouraging to others.

Editor's Note: We will supply active astrophotographers with a longer list of H-alpha nebulae to photograph if, *when you submit deep sky photographs*, you request our Extended List of Deep Sky Nebulae.

At left is the magnificent nebula around Lambda Orionis. Photograph courtesy of Yerkes Observatory. At right, the Rosette (lower right), totally overexposed, allows the faint tracing of NGC-2264 to be brought into prominence. Photograph courtesy of MacDonald Observatory. Both photographs were taken with 30 second exposures on 103aE films using red filters at the focus of an eight inch f/1 Schmidt camera.

John Davis recently received his Ph.D for ultraviolet observations from the Orbiting Astronomical Observatory; William Tobin is a graduate student, and Joel Eaton, a recent Ph.D, is interested in eclipsing binary stars. Their photos were taken "for the fun of it" from Pine Bluff Observatory of the University of Wisconsin at Madison.

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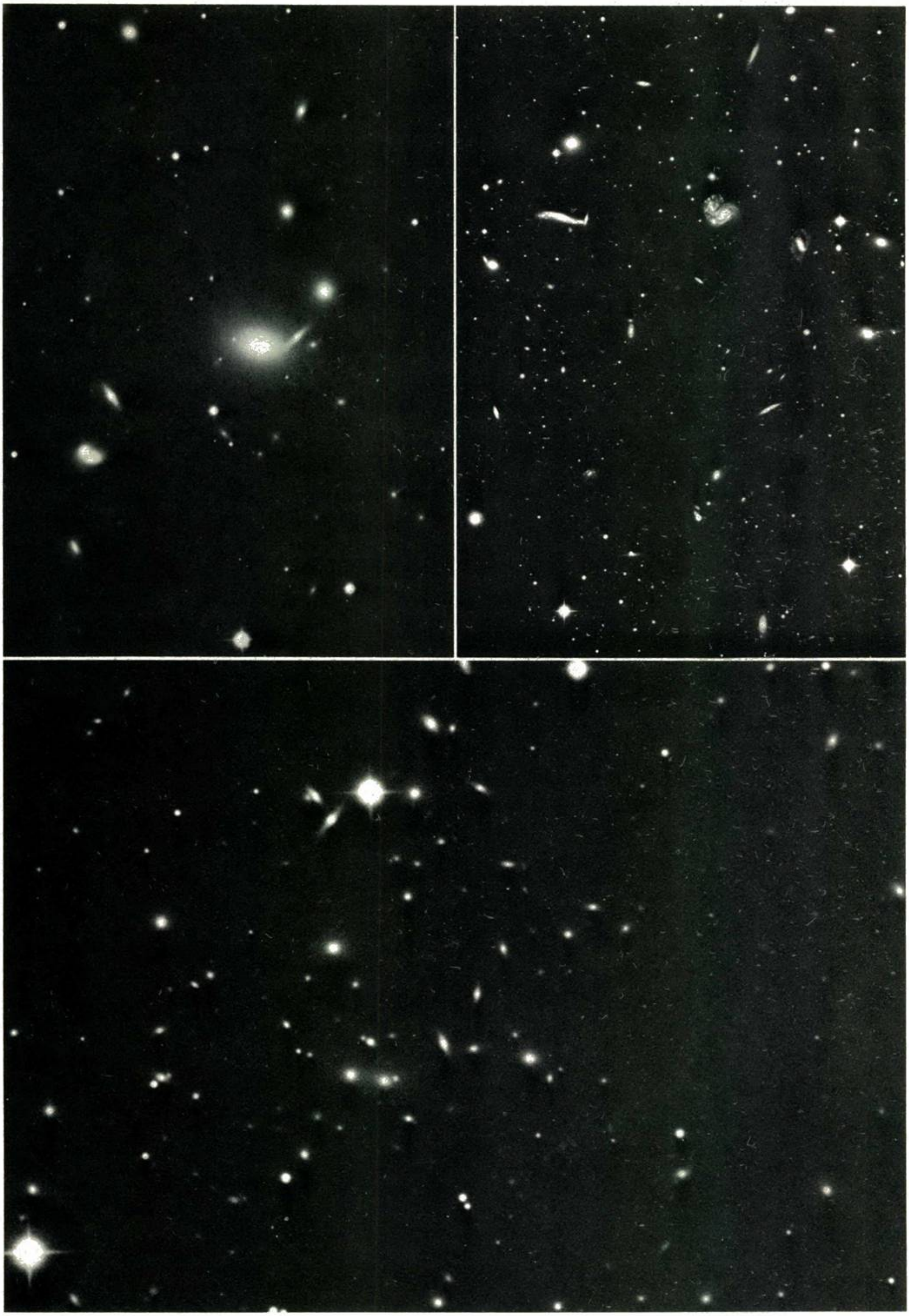
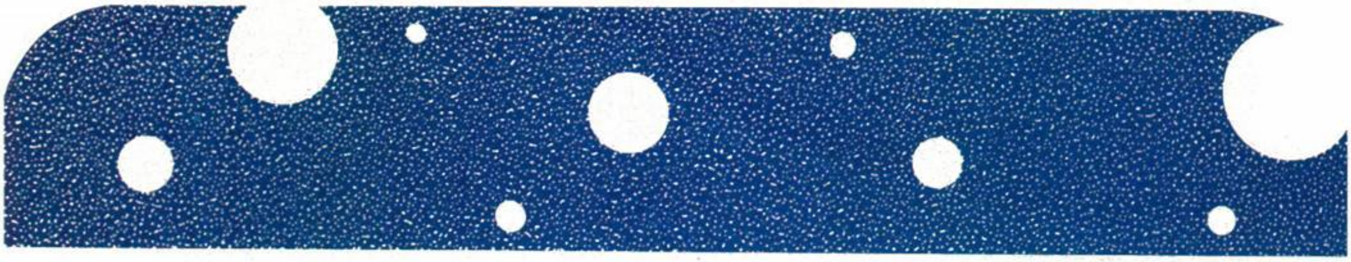




STELLAR FRONTIERS

Clusters of Galaxy Clusters

by
Gerrit L. Verschuur

Our galaxy, the Milky Way, is basically a large cluster of a few hundred billion stars lying in a disk shaped region of space (typical of spiral galaxies) and containing many clusters and associations of stars.

Recent investigations into the phenomenon of clustering show that it does not occur on any preferred basis. Instead, clustering occurs on *all* scales, from a single galaxy to possibly the entire observable universe. At the other extreme — that of particles such as atoms — clustering also seems to occur. Protons might be clusters of still smaller particles (various types of quarks). In fact, we might even think of our solar system as a cluster containing one star, nine planets, several dozen moons, and plentiful smaller bodies.

The clustering phenomenon continues when we examine nearby galaxies: They form groups whose members are associated with one another. Our Milky Way is located in such a group called, simply, the Local Group. The best counts indicate that the Local Group contains about 27 member galaxies. Many of these are small, inconspicuous objects. But the Local Group also includes some of the better known galaxies, such as M-31 in Andromeda, M-33 in Triangulum, and the Magellanic Clouds of the southern skies.

By definition, a *group* of galaxies (the Local Group is a good example) is a clump of less than 10 to several dozen galaxies. A group that exists on a larger scale, with more members, is known as a *cluster* of galaxies. Clusters may contain up to 1,000 galaxies, all apparently born many billions of years ago from one gigantic cloud of gas. Members of these aggregations of galaxies seem to be bound together by gravitational force.

Lately it has been suggested that the groups and clusters of galaxies closest to our own may combine to form sort of a supergalaxy. Astronomers have deduced the supergalaxy's existence by examining the distribution of some of the nearer collections of galaxies (those within 50 million light-years of us). We find that they lie predominantly along the equator of a hypothetical supergalaxy, just as the nearby stars in our own galaxy lie along its equator.

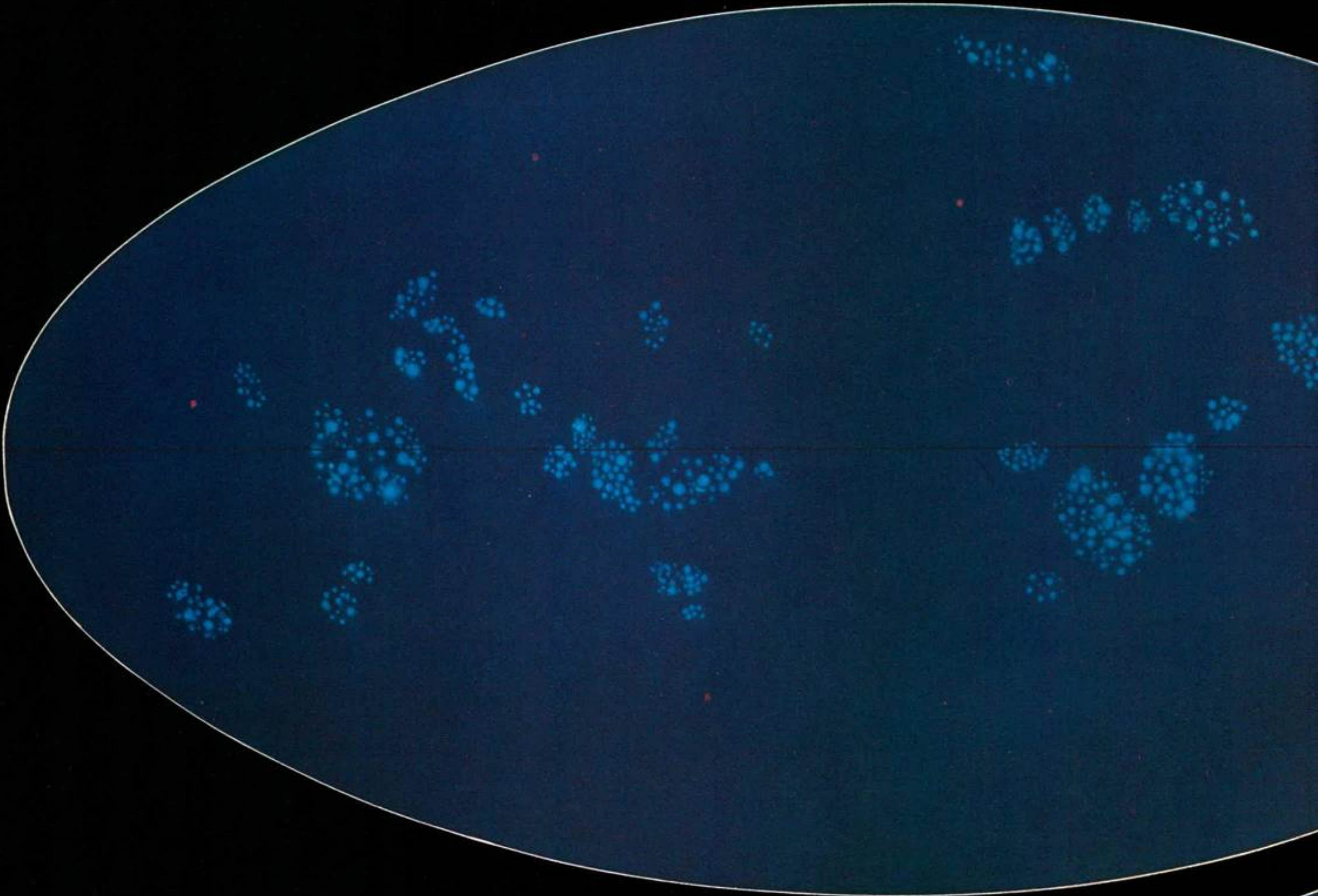
While not all astronomers agree that the supergalaxy exists, there is some evidence (although circumstantial) attesting to its reality.

There is also evidence that distant clusters of galaxies also are collected in groups similar to the local supergalaxy. We might, therefore, imagine a whole universe full of supergalaxies. There's no way of telling at present whether or not there is organization on an even bigger scale.

Astronomers visualize the local supergalaxy as a flattened system with an estimated diameter of 100 to 200 million light-years and a thickness of about 20 million light-years. According to one estimate, our galaxy must move about the nominal center of this supergalaxy at approximately 300 miles per second, taking 100 billion years for a single round trip. Since this is a time much greater than the age of the entire universe, it's hard to see how a supergalaxy could even have been formed and set in motion in the first place! Such motion, however, is extremely difficult to detect and might not be real.

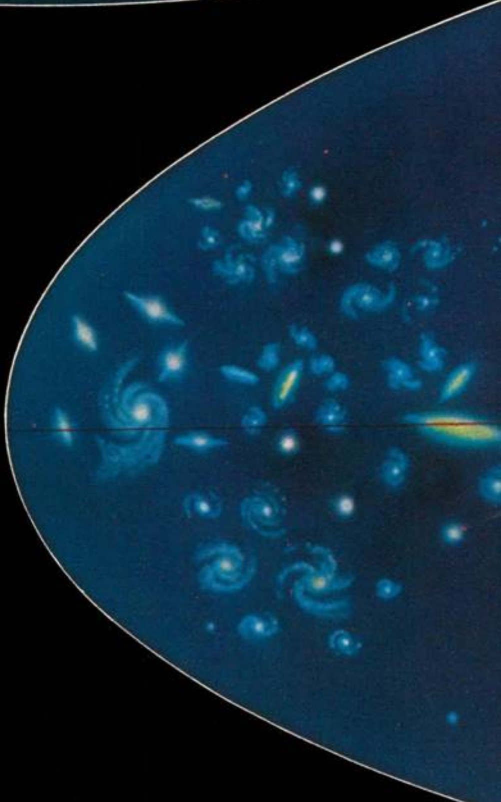
The evidence that such a supergalaxy is a flattened system is somewhat similar to the appear-

Top: The Coma Berenices cluster of galaxies, some 450 million light-years from our galaxy, contains almost no spirals, but plenty of elliptical galaxies and lenticulars. Lower left: The Hercules cluster is ragged, irregular and full of spirals. Its distance is about 700 million light-years. Lower right: Corona Borealis, about 1-1/3 billion light-years distant, is rich, regular, and contains ellipticals. Hale Observatories photographs.



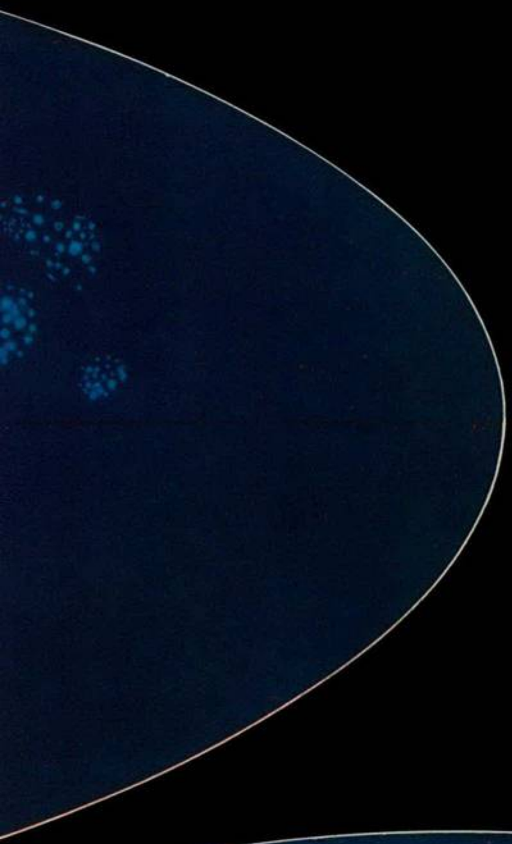
ance of a clear night sky that indicates we live in a flattened disk of stars called the Milky Way. We see our galaxy as a band of stars because we look along the disk of the galaxy into its long dimension. As a result we see many more stars than we do in directions at right angles to the galactic equator. A similar effect occurs when we look at distant galaxies. The apparent evidence that they, too, lie in a band (highly inclined to the Milky Way) is analogous to the distribution of stars in the sky. The band of galaxies seems to indicate the existence of a similarly flattened supergalaxy whose member objects are entire galaxies, not stars.

A recent cosmological theory states that galaxies, in addition to being gathered into groups and clusters, are also bound together in huge supergalaxies. Those who support this theory cite the apparent distribution of galaxies along a "supergalactic equator" — somewhat similar to the arrangement of nearby stars into the band of the Milky Way — and consider this apparent clustering as evidence of a huge "spiral arm" type of arrangement. The theory's opponents state that this arrangement is an illusion produced by the presence of the stars and dust of the Milky Way, which blocks galaxies behind it from our sight. The diagram at right shows the arrangement of galaxies out to about 50 million light-years; the supergalactic equator is indicated by the red line. Artwork by Mark Paternostro.

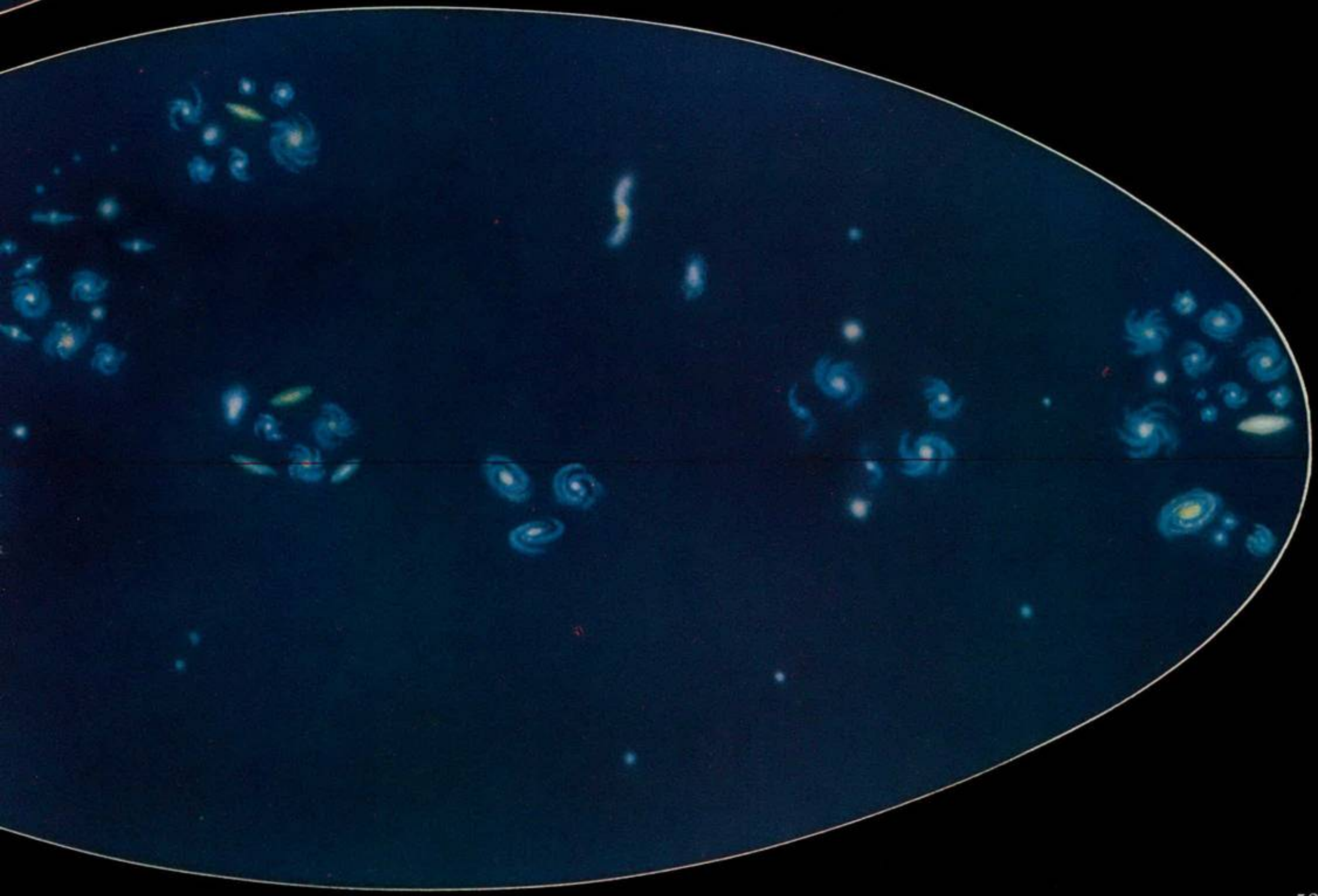


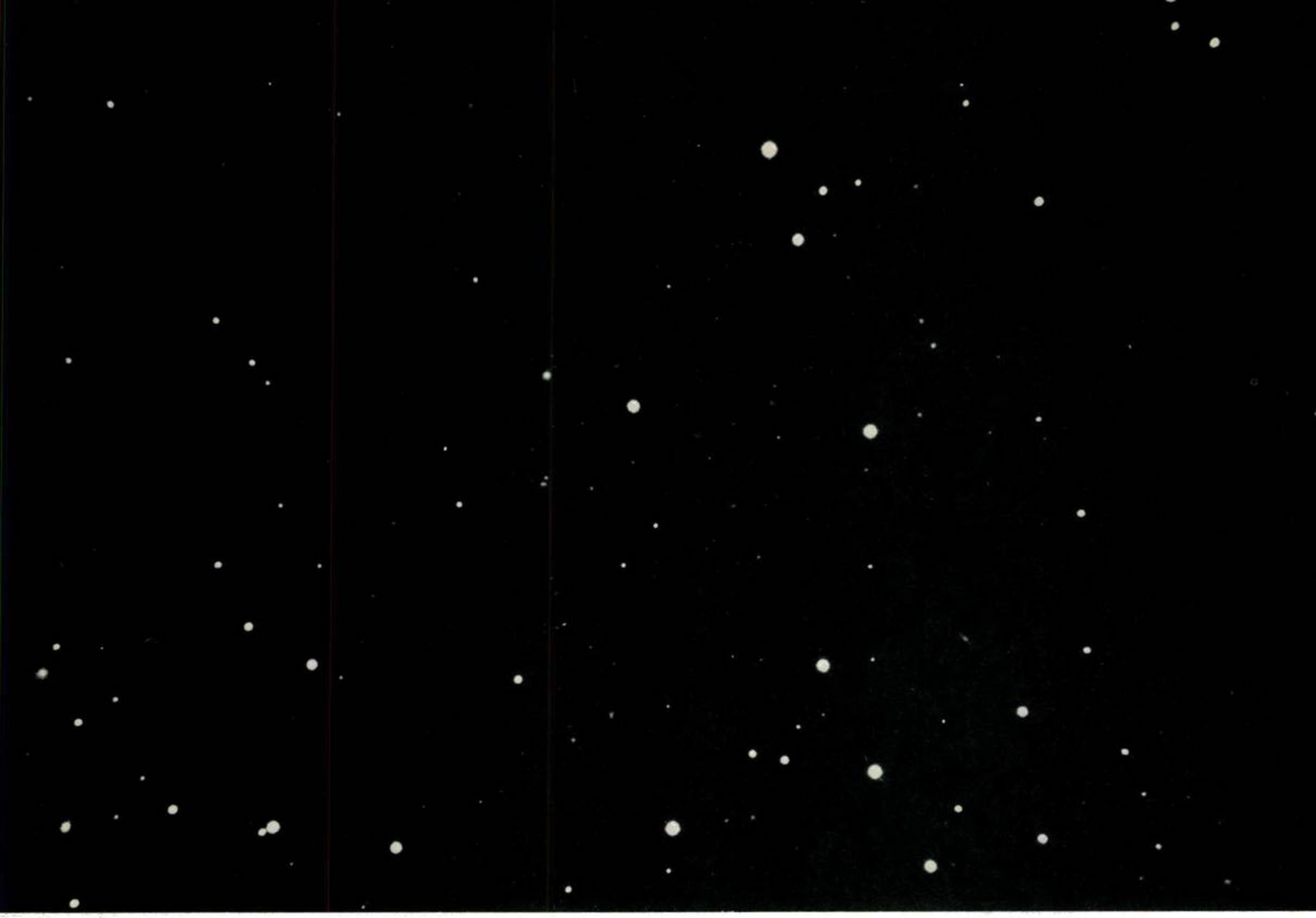
The center of the supergalaxy is believed to lie in the direction of the constellation Virgo. A huge cluster of galaxies containing perhaps 1,000 members is located here; it's among the largest of the tens of thousands of galaxy clusters known. The total mass of the supergalaxy may be as great as a quadrillion (10^{15}) star masses.

We can best appreciate the enormous scale of the supergalaxy by comparing it with that of our own galaxy and the surrounding area. The size of a typical star cluster in the Milky Way ranges from a few dozen to a few hundred light-years across; the galaxy itself is about 100,000 light-years in diameter. The



Galaxies more distant than 50 million light-years are plotted on the chart at left, similar to the one below. The theory of the supergalaxy states that the apparent clustering of galaxy clusters shows that they are arranged in large flattened systems analogous to normal spiral galaxies. The largest group at the diagram's right indicates the Coma-Virgo cluster, one of the largest clusters of galaxies known. Most of the theory's proponents state that there are a large number of these supergalaxies; some take the apparent evidence still further and hypothesize a universe of galaxies arranged in one enormous system that contains our entire universe. Those who accept the big bang theory of the universe's origins sometimes offer it as explanation for the apparent cosmic order.





Clusters of galaxies exist at all distances from the Milky Way. Those that are relatively near are fairly bright and obvious, while those more distant are dimmer and harder to find (though their distance makes them appear more closely packed). This photograph shows a cluster of galaxies in the constellation Hydra; its distance is estimated at 700 million light-years. Hale Observatories photograph.

Magellanic Clouds, our nearest neighbor galaxies, are about 160,000 light-years away, while M-31 is some two million light-years distant. The diameter of our Local Group of galaxies is five to six million light-years. About 15 other groups of galaxies lie within 30 million light-years, and another 40 groups and clusters are between 30 and 50 million light-years away. These clusters lie roughly along the supergalactic equator, as shown in the diagram on page — although there are, of course, exceptions. These groups of galaxies may have formed within an enormous primeval cloud of gas 15 billion years ago, much as star clusters formed in the spiral arms of our galaxy.

Remarkably, the majority of galaxies within the supergalaxy — including all common spiral galaxies — are themselves flattened, and generally the direction of their flattening seems to be the same as that of the supergalaxy. Perhaps some process involving rotation of the primeval gas cloud controlled the formation of the individual galaxies.

How could the clusters or groups of galaxies that comprise the supergalaxy arise in the first place? If we accept the theory that most matter in the universe formed in the big bang, we must then give some thought to the chain of events that took place as the universe expanded. There must inevitably have been some slight irregularities within the universe as it expanded and cooled, and the pull between these random irrgularities held some of them in regions that became separated from each other. In other words, clumps formed, which were later to be the birthplaces of the galaxy clusters. In turn, and on a smaller scale within the protogalaxy cluster clouds, there were additional subunits that became gravitationally tied together that formed the protogalaxies themselves. These individual clouds eventually broke into subunits that became clusters of stars.

Thus, according to this theory, we find a whole hierarchy of condensations occurring in the universe as far down as the formation of stars, with their accompanying planets and moons. But while our theories of star and planet formation seem to be fairly sound, the formation of the galaxies themselves is a much more complex and difficult problem to unravel — and the formation of clusters of galaxies, or the supergalaxy, is almost a complete mystery; we can only make reasonably intelligent guesses. It's tempting to draw analogies between the formation of various objects in their hierarchy,

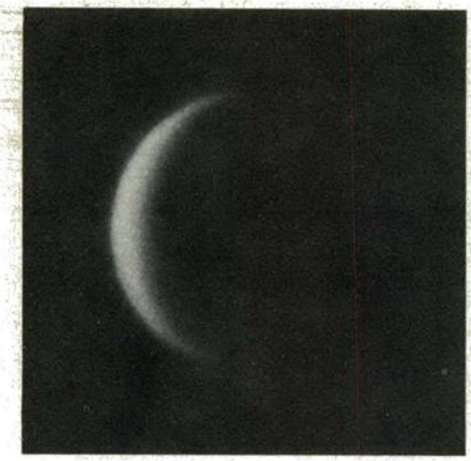
An idea of the enormous scale of the universe can be had from this picture of a cluster of galaxies in Pisces, lying at the limit of the observable universe. At this distance, the Andromeda galaxy (M-31) would look no brighter than the brightest member of the Pisces cluster. Whether such clusters as these belong to a huge supergalaxy has yet to be determined. Hale Observatories photograph.

but such analogies tend to be misleading since they ignore essential differences between the vastly different scales of time and size.

Studies of unusual clouds of hydrogen gas that appear to be approaching our galaxy have recently provided totally unexpected new evidence supporting the existence of the local supergalaxy. Scientists have proposed several different explanations for these clouds (called *high velocity clouds*), including the suggestions that matter may be falling into the Milky Way from intergalactic space, or that matter may drift between the galaxies at distances similar to those of the Magellanic Clouds or M-31. Alternatively, the gas may be part of the spiral structure of our galaxy — that lying most distant from the nucleus. The high velocity clouds, however, apparently lie primarily near the equator of the supergalaxy; they may be stretched along it! Perhaps the clouds float between the galaxies — some of them between members of the Local Group and others between the components of more distant groups of galaxies. Possibly they represent the matter remaining after galaxy formation — matter that never was able to begin the process of star formation. Somewhat similar clouds of hydrogen have been detected near the galaxies M-31, M-33 and M-81, and the clouds are apparently directly associated with these galaxies.

The largest nearby high velocity cloud, called the Magellanic Stream, forms a long tongue of gas many hundreds of thousands of light-years in extent that links the Milky Way to the Magellanic Clouds. It is possible that the Magellanic Clouds and the gas stream, with the clumpiness seen within it, all formed billions of years ago from a single cloud of matter. The Magellanic Clouds grew dense enough to form stars while the rest of the gas continued to swirl about in space. If this picture is correct, these are the first observations of extended clouds of intergalactic matter.

Don't try to find the local supergalaxy at your next observing session — it's a phenomenon that is impossible to observe visually. Superclustering is, after all, one of the more esoteric properties of the universe so far discovered by astronomers. If you want to imagine further groupings beyond that mentioned here, feel free. For example, might we speculate on groups of universes? How far can we take the hierarchical picture down into the microcosm? Such questions must today remain unanswered.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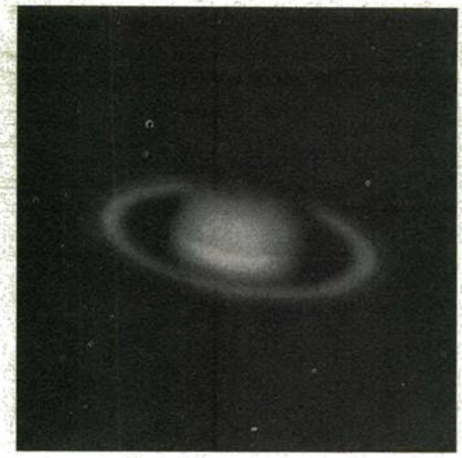
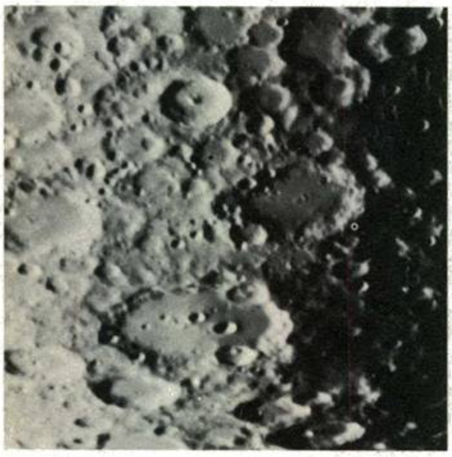

The Rings of Saturn

Jupiter's Cloud Belts


Clavius and Tycho

The Crab Nebula

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Open Cluster M 11

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ASTRO-NEWS

Latest News From the World of Astronomy

Comet West to Yield Clues To Early Solar System

During the first two weeks of March, comet West (1975n) put on a show that rewarded the early riser with a glimpse of a special phenomenon that provided astronomers with important clues to the early solar system. Results of many scientific experiments will not be available for months, but armed with interpretations of past comets, we can look at a few of the comet's characteristic features that anyone with an ordinary camera and small telescope could record.

Although comets share basic similarities, they also appear quite individual to the observer on Earth due to differences in orbital elements and viewing geometry, as well as intrinsic physical differences. According to early calculations by Brian Marsden of the Smithsonian Astrophysical Observatory, comet West is a long period comet traveling in a nearly parabolic orbit inclined about 43 degrees to the ecliptic. It approached from the south and had a perihelion distance of about 18.5 million miles.

The comet was bright enough shortly after perihelion (which occurred on Feb. 25) to be seen with a six inch telescope in broad daylight. The reason was apparent a few days later: After moving away from the sun's glare, a highly structured dust tail was seen stretching more than 20 degrees behind the nucleus. The high, variable production of dust at perihelion produced synchrones whose change in position reflected the change of the comet's position as it moved around the sun.

A generalized scenario of what is thought to happen to a comet can help us interpret what was seen in comet West. First, the nucleus, believed to be somewhere between one and six miles in diameter, is an icy amalgamation of dust grains; some grains are silicates ranging in diameter from .025 inch to less than .000025 inch. The distribution of dust in the nucleus is unknown, but comet West appeared to display an inhomogeneous mixture. As the comet approached the sun, it heated up and the ices (probably water, methane and ammonia) vaporized. The outgasing pressure drove the dust away from the nucleus. When the dust no longer collided with gas molecules, solar radiation pressure drove the dust particles away from the sun to form the dust (or type II) tail. At the same time, some of the gases went through photodissociation and florescence processes. The produced gaseous ions were accelerated by the solar wind and associated magnetic field to velocities over 9,000 m.p.h.

The gas (type I) tail was viewed distinct from the type II tail because of its different positional angle. This "double tail" became more prominent as the type I component became more pronounced and was particularly striking in color photographs, since the type I tail was blue. A look at an objective prism spectrum of the comet shows why this was true.

When the light of the comet was broken into a spectrum, a series of emission features were present. The most common was due to carbon and cyanogen molecules (including the somewhat rare C_3 molecule) in the coma and ionized carbon monoxide (CO^+) in the type I tail. Overlying this is a solar continuum from solid dust particles reflecting sunlight. The relative intensities of the emissions vary from comet to comet. Whether this variation is due to intrinsic composition differences or age (how many times the comet has come close to the sun and expended some of its volatiles) is unknown. The spectrum of comet West's tail indicated well develop-

West *continued on page 59*

Comet Orbits Point To Former 10th Planet

An astronomer at the United States Naval Observatory believes there is solid evidence that a giant planet existed between the orbits of Mars and Jupiter about six million years ago.

Dr. Thomas C. Van Flandern based his findings on the computer plottings of the orbits of 60 very-long-period comets that may have originated from the explosion of the giant planet.

In tracing the orbits of these comets — each has been seen only once from Earth — Van Flandern found there is a tendency for the orbits to intersect at a common point located in the asteroid belt. The asteroid belt, confined primarily to the area between the orbits of Mars and Jupiter, has been suspected since its discovery of being the by-product of a former planet.

Van Flandern said that although the orbits scatter all over the sky, they tend to cluster near 249 degrees ecliptic longitude. The clustering is statistically significant: At the center of the cluster, four orbits intersect within 0.01 cubic degrees.

The cause of the theorized giant planet's break-up is unknown.

The results of Van Flandern's work support the theory proposed in 1972 by University of British Columbia astronomer M.W. Ovenden. Ovenden said there were strong indications that a former planet existed in the asteroid belt between Mars and Jupiter with a mass 90 times that of Earth.

The idea that the break-up of a planet is responsible for the presence of the asteroid belt is not new. German astronomer Johann Bode devised a formula (Bode's law) two centuries ago for predicting the planets' distances from the sun. His formula predicted that a planet existed between Mars and Jupiter, but none was found.

Theory Proposes Planetary System Forming in Binary

Epsilon Aurigae, a long-standing puzzle star for astronomers, is the remarkable instance of a binary system in which a planetary system is currently forming, according to a theory proposed by two British mathematicians.

A third magnitude yellow supergiant star, Epsilon Aurigae is eclipsed every 27 years by a mysterious dark companion. The fact that this companion star is invisible has led to speculation that it is a black hole, although this has not been borne out by subsequent x-ray observations.

Michael Handbury and Iwan Williams of the University of London suggest that Epsilon Aurigae is actually a very young star about nine times as massive as our sun, and still contracting onto the main sequence. Its dark companion is so young that it has not yet "switched on" to become a star. The companion is surrounded by a disk shaped nebula in which planets may be forming.

The true shape and nature of the secondary companion to Epsilon Aurigae is revealed by the peculiar light curve of the eclipses it produces. The whole eclipse lasts a remarkable two years. Minimum light output, during which Epsilon Aurigae is dimmed by 50 percent, lasts 330 days.

To account for this behavior, Handbury and Williams believe the obscuring body cannot be a simple spherical star (or a black hole), but instead must be shaped like a flattened disk, growing transparent toward its edges. The obscuring disk is about one billion miles in diameter and contains approximately 10 solar masses. Most of the mass is concentrated in a forming central star, with the remainder collecting into a planetary system around it.

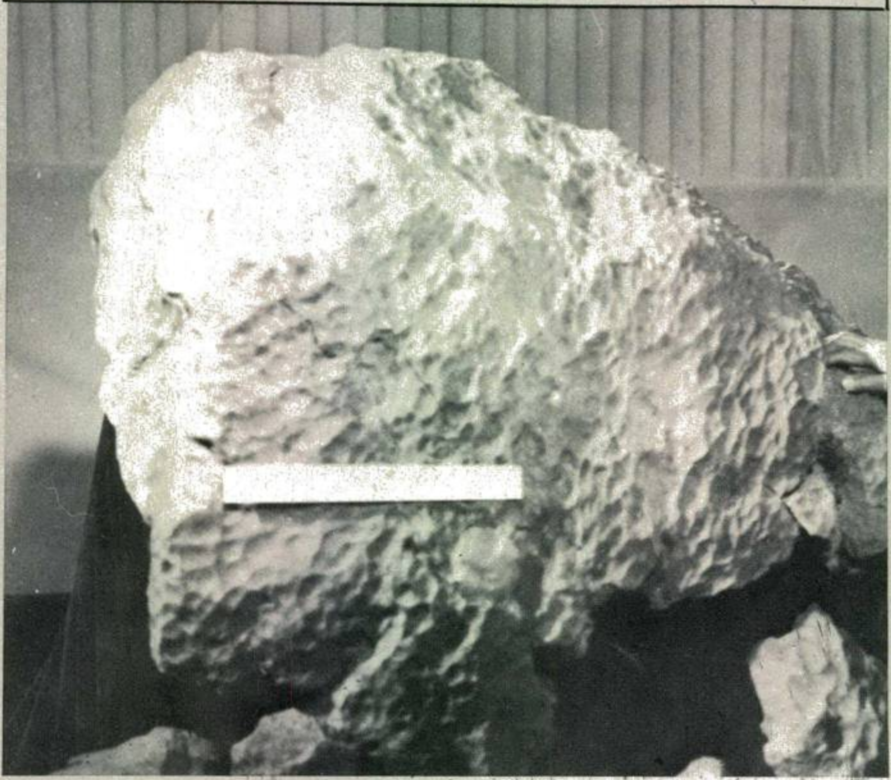
Because the two stars of the binary are so far apart — about two billion miles — planets can form in stable orbits, similar to the stable orbits of Jupiter's satellites.

The Handbury-Williams model is particularly important because it means that the binary becomes one of the best candidates for observing solar system formation in action. So far, only RU Lupi, a star of the T Tauri variety, has looked as promising. In 1974, four Swedish astronomers suggested that RU Lupi was surrounded by a swarm of protoplanets.

Confirmation of planets in the Epsilon Aurigae system will settle the long-standing argument among astronomers of whether planets can ever form around double stars, with consequent implications for the existence of extraterrestrial life.

If the dark companion of Epsilon Aurigae is a star in the process of formation, it might become visible in the near future. Certainly, the next eclipse of the system in 1982 will be the object of a great deal of astronomical attention.

Meteorite Falls in China



The 3,894 pound Kirin meteorite is shown with some of the fragments which broke off on impact. The fall, which took place around 4 p.m. on March 8, scattered fragments over a 200 square mile area. The Kirin meteorite broke the previous world's record of 2,372 pounds which was attributed to a 1948 meteorite which fell in a cornfield in Norton County, Kans.

X-Ray Nova Sources Growing in Number

X-ray novae are a new class of x-ray sources that must be added to the growing list of such objects. The first source, Cen X-2, was spotted in Centaurus in 1967. Last year a spectacular x-ray nova appeared in the constellation Monoceros and became the brightest x-ray source in the sky. In addition, during April 1975 an object near the Crab nebula, AO535 + 26, was observed to pulsate once every 104 seconds. The latter source faded in July, reappeared in August and faded again, and then reappeared in November.

Two MIT scientists, Philip Morrison and Kenneth Brecher, have suggested that these new sources be divided into two groups. Sources like the brilliant one on Monoceros are "soft" x-ray objects that may generate radiation by ejected gases being excited by shock waves traveling through the nova. On the other hand, "hard" sources like AO535 + 26 may emit x-rays in the manner of neutron stars, by the excitation of matter falling onto a magnetized, rapidly rotating collapsed body.

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X-Ray Data Indicates Black Hole Centered In Globular Cluster

A team of astronomers at the Center for Astrophysics in Cambridge, Mass. has found evidence for a massive black hole in the center of the globular cluster NGC-6624, about 15,000 light-years away. The astronomers estimate the black hole's mass is 1,000 times that of the sun.

Analyzing the x-ray data gathered by the Astronomical Netherlands Satellite launched in 1975, the researchers found that the center of the cluster emitted two very intense x-ray bursts in March and September of that year. The x-ray energy given off during the bursts was a million times greater than the total light generated by the sun.

Present theories suggest that x-rays are produced in a close binary system in which one member is either a neutron star or a black hole. When the "normal" star swells into a red giant, some of its material escapes and spirals down onto its invisible companion. The already hot material gains more energy as it spirals, eventually becoming hot enough to emit x-rays before disappearing into the black hole.

Globular clusters are very densely packed groups of up to a million stars each, situated around the outskirts of the galaxy. Probably as old as the Milky Way, they lack interstellar dust or gas; both have long since been incorporated into stars. The centers of globular clusters are so packed with stars that astronomers cannot distinguish individual stars.

Since globular clusters are so old, any very massive stars that originally were present would have long since completed their evolution to neutron stars or black holes. Over the eons, they would gradually have sunk toward the densely packed center, where they would capture and fuse any field stars that approached too closely. A supermassive black hole might be built up in this way.

BRIEFS

- More x-ray burst sources have been discovered by the SAS-3 and ANS astronomical satellites. First discovered last December in the region of a globular cluster in the constellation Sagittarius, two more have been located near the galactic core and two have been found in the constellation Scorpius. One of the bursters, as they are sometimes called, has a burst strength about equal to that of the Crab nebula.

Walter Lewin, head of the Massachusetts Institute of Technology team that first discovered the sources, believes the bursters are binaries with a neutron star component. Because the collapsed star has a strong magnetic field, material flowing from the normal star toward its companion builds up until the field no longer can contain it. Matter then pours through and rapidly heats up, emitting bursts of x-rays.

- The validity of the inverse square law at laboratory distances for gravity has been questioned by an Eastern Washington State College scientist. In a recent issue of **Nature**, D. R. Long stated that accurate determinations of the gravitational constant (G) suggests that the value of G increases as the separation between attracting masses increases. He found a discrepancy of 0.37 percent in the value of G.

The inverse-square law has been verified by astronomers for planetary motions, although one researcher demonstrated that a slight modification in the law's form could explain slight anomalies in Mercury's motion. Long said, however, that what might be true at astronomical distances might not be true at laboratory distances.

Long said his experimental results are consistent with past laboratory measurements of G. Convincing fellow scientists of this may not be so easy. The scientists stressed, however, that the important thing is to get someone to duplicate the experiment to see if his results are reliable.

West

continued from page 57

ed CO+ emission showing up as monochromatic straight tail images in the blue end of the spectrum. The type II tail simply shows a continuous spectrum with peak intensity around 5,500 angstroms. Comet Kohoutek did not show a good separation of its tails; color film was used to help identify the comet's tails. Comet West did not have this problem, since color differences were obvious, giving the comet an especially asthetic appeal.

The tails grew fainter as they diffused into space and the production rate of new material decreased as the comet moved away from the sun.

Small instruments showed daily changes in the coma close to the nucleus. They were subtle changes, hinting at some kind of activity in the nucleus. Detail in the coma was nothing like the striking spiral structure observed in comet Bennett in 1970. The objective prism spectrum had emission features of carbon (both C_2 and C_3), cyanogen, sodium and methylidyne associated with the coma. Slit spectra obtained with large telescopes showed much more.

Perhaps the most spectacular phenomenon of comet West was the splitting of the nucleus into several pieces during and after perihelion passage. Several observers noticed a secondary nucleus which parted slowly from the primary. By mid-March, observers at New Mexico State University Observatory photographed four distinct nuclei slowly spreading apart. Photographs with the Mt. Lemmon Observatory 61 inch telescope showed their relative brightness changed by as much as 20 percent. Each nucleus developed its own tail, probably a gaseous one of CO+. Tracing the motions of the four bright, separate nuclei back in time, it appears that the nucleus first split around Feb. 25. On March 9 or 10, the secondary piece broke again, leaving behind a piece almost motionless with respect to the first (all these motions refer to proper motions in the plane of the sky, since there is no available radial velocity data).

This sort of observation is consistent with an icy conglomerate nucleus with an inhomogeneous mixture of volatiles that may produce fractures. Another consequence of inhomogeneous mixture might be jets of gases that may be large enough to impart more spin and cause break-up. Observations argue against a loose sandbank model of particles rotating about a center of mass, since such a configuration could not break up into several well defined groups of nearly the same visual magnitude.

It appears that we witnessed a clump of primitive solar system material, kept intact in the deep freeze far from the disruptive forces of the sun, which was "recently" perturbed. There is still a great deal to learn from satellite observations made in the ultraviolet and application of new ground based techniques on the spatial and temporal distribution of the comet's components. But, our understanding and appreciation of the "hairy" members of the solar family has deepened.

'Missing' Gas Clouds Found Betweeen Galaxies

One of the tests of the modern cosmological view that the universe will expand forever — the big bang theory — is the amount of matter in the universe. Measurements of the universe's mass, derived from the relative motions of galaxies, indicate there is not enough matter to halt and reverse the general expansion of the universe. However, two astronomers have presented evidence of large clouds of gas existing in the previously-believed empty spaces between galaxies. The overlooked quantity of matter might be enough to produce gravitational forces to overcome the universe's expansion.

Robert E. Williams and Ray J. Weymann discovered the intergalactic gas clouds while studying the nature of quasars and the clouds of matter supposedly associated with them. The scientists found that the gas clouds are linked with clusters of galaxies containing quasars, furnishing clues on the evolutionary scheme of galactic clusters.

Although surrounding clouds of gas are not visible on photographs of quasars, spectral studies reveal their presence. Absorption lines in quasar spectra indicate clouds of matter lying between quasars and us absorb a portion of their light. Scientists were led to believe that these gaseous clouds were associated with quasars.

Some clouds, however, appeared to be moving toward their hosts, although most were moving away from quasars. Reasoning that the mass of a quasar might be determined from an approaching cloud, Williams and Weymann began their studies.

Using the 90 inch Steward Observatory telescope at Kitt Peak, the two researchers established that the light from one quasar (PHL 1222) was passing through several clouds; one of the clouds was moving toward the quasar. The approaching cloud, Williams said, "is composed of atoms having low ionization or small positive electric charge(s). Since any matter near a quasar would be highly ionized, the cloud must be at a great distance from the quasar." He estimated its distance from its host to be "at least 1,000,000 light-years."

The gas cloud was found to be moving at 1,500 m.p.h. toward the quasars. The gravitational attraction of a quasar is not strong enough to account for the cloud's speed at these distances. Only the largest clusters of galaxies, Williams observed, have large enough masses to account for the necessary attracting forces.

"The evidence indicates that the cloud which is moving toward PHL 1222 is not attracted by the quasar or even directly associated with it," Williams said. "Rather, it is moving under the influence of a cluster of galaxies which contains the quasar."

The existence of such gas clouds suggests there is a substantial amount of matter present between galaxies, and might account for a good portion of the "missing" matter that steady state theorists believe exists. Current estimates of the average density of matter show there is far too little matter present to halt the observed expansion.

Neutrino Count Levels Debated

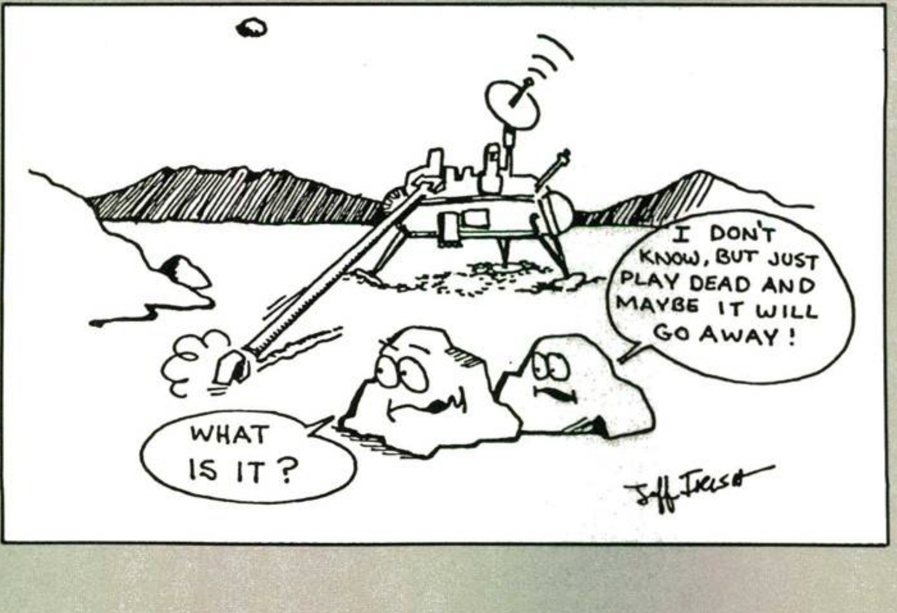
For 15 years, Dr. Raymond Davis Jr.'s 100,000 gallon neutrino telescope has yielded low particle count levels, touching off speculation and concern about the reliability of the solar energy model. Four recent data runs at the neutrino "telescope" (in a mine beneath Lead, S.D.) have returned neutrino counts that approach the predicted levels. Optimistic observers greeted the news with statements that Davis' equipment was at fault in the past and the mystery of the missing neutrinos is now solved.

Davis disagrees with both conclusions. Refinements in the efficiency of detected argon nuclei (produced by the interaction of neutrinos and chlorine atoms) have increased the detection rate, but the change in efficiency has been corrected for. Also, the unprecedented high levels, Davis told **Science News**, are merely part of the expected statistical fluctuations. The predicted flux of solar neutrinos, he feels, is not yet warranted.

Davis hopes to build a neutrino detector containing 20 tons ($60 million worth) of gallium. His detector presently uses a relatively cheap dry cleaning fluid sensitive to high energy neutrinos. Gallium would probably increase detection rates since it is sensitive to the low energy neutrinos generated by the primary burning process held in the sun's core.

A number of theories suggest there are fluctuations in the sun's neutrino output, but Davis believes there is little likelihood that such a variation exists. There is a slight possibility of an 18 month period in the sun's nuclear output, but this has not yet been established.

The neutrino detector is buried underground to shield it from virtually all particles except neutrinos.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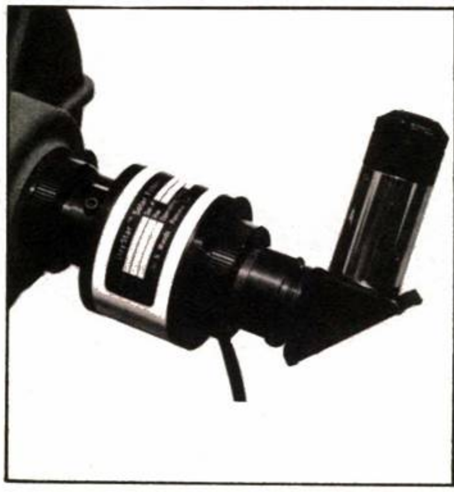

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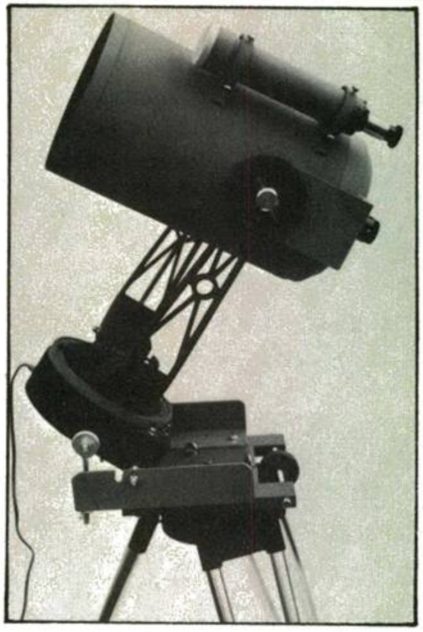

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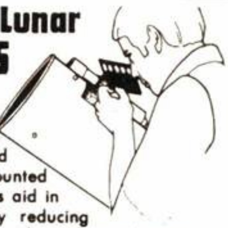

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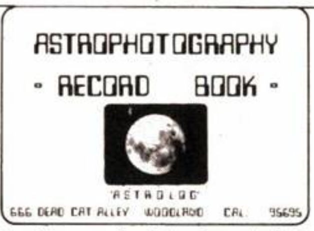

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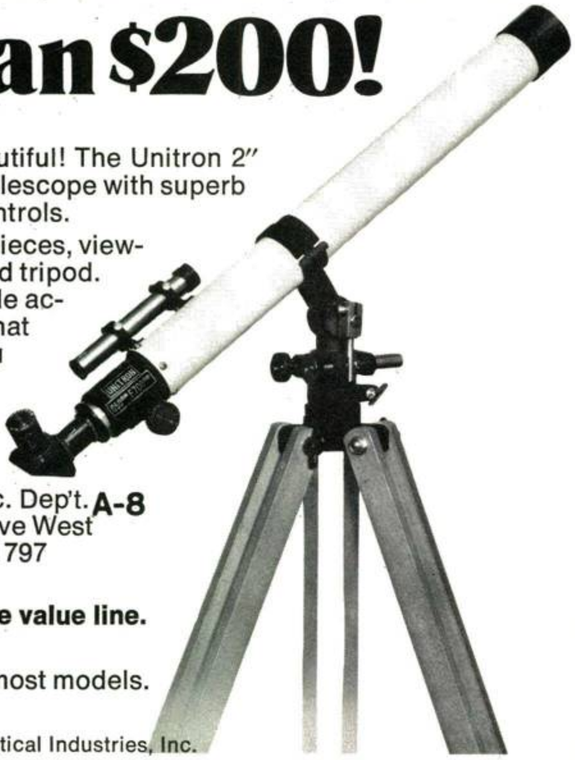

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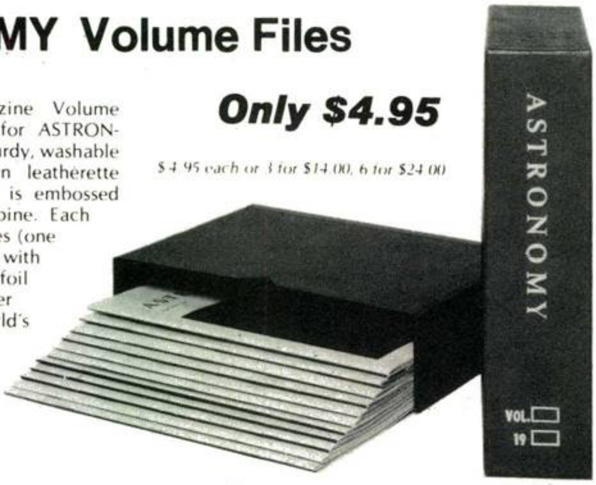

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ASTRONOMY

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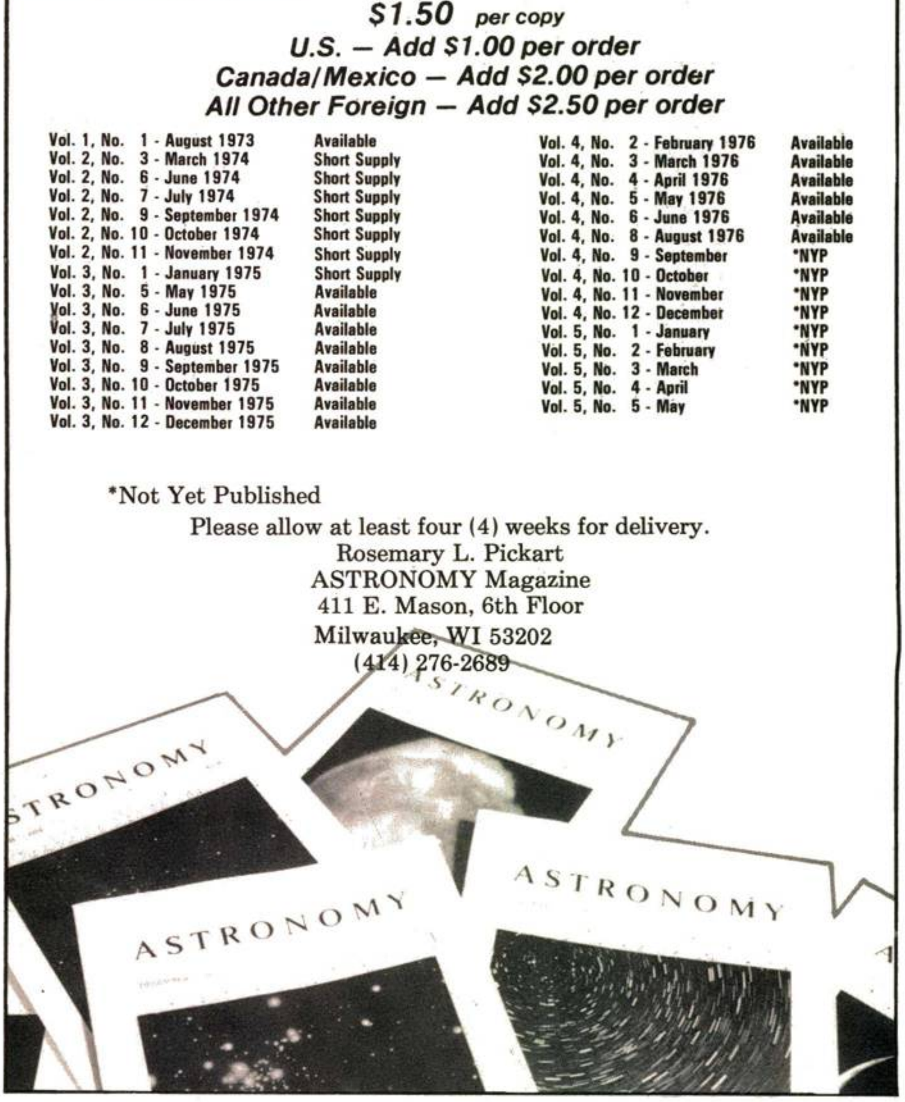

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STAR DOME

AUGUST

by

James Mullaney and Henry J. Phillips

To some, our galaxy rises from the horizon on August nights like a boiling cloud of steam. We might see it as the smear left by a giant's paintbrush, or — referring to our own name for it — a streaming puddle of spilled milk. Any such comparisons, however, pale beside the actuality of the Milky Way: our own spiral galaxy, composed of billions of stars and vast clouds of dust and gas.

Many bright stars dot the Milky Way as it stretches from Sagittarius to Cygnus; most dominant are the three that comprise the summer triangle — Vega, Deneb and Altair. The constellation patterns themselves include some of the sky's most distinctive groups: the Northern Cross in Cygnus, the teapot in Sagittarius, the row of three stars in Aquila, and the tiny figures of Sagitta the arrow and Delphinus the dolphin.

Another small constellation, set directly in the Milky Way, is Scutum the shield. Invented by Hevelius, its original name was Scutum Sobieskii; it was "placed" in the sky in honor of John Sobieski, king of Poland, who prevented the Turkish invasion of Vienna in 1683. Scutum is notable today not for any bright stars, but for the richness of the Milky Way within its borders.

The Milky Way itself is the subject of innumerable legends and bits of folklore. Often depicted as a river, it has had many different names. In Arabia it was simply Al Nahr (the river); in ancient Mesopotamia it was river of the Divine Lady, wife of the heaven-god; in Japan, the Milky Way was the Silver River. When the crescent moon was in the sky, the fish in the river were said to be frightened, believing the moon was a hook.

The most widespread conception of the Milky Way, however, is that of the road. We find this idea in our own title, for the word "way" is an archaic synonym for "road" or "path". The German Milch Strasse has the same meaning, as does the French Voie lactée.

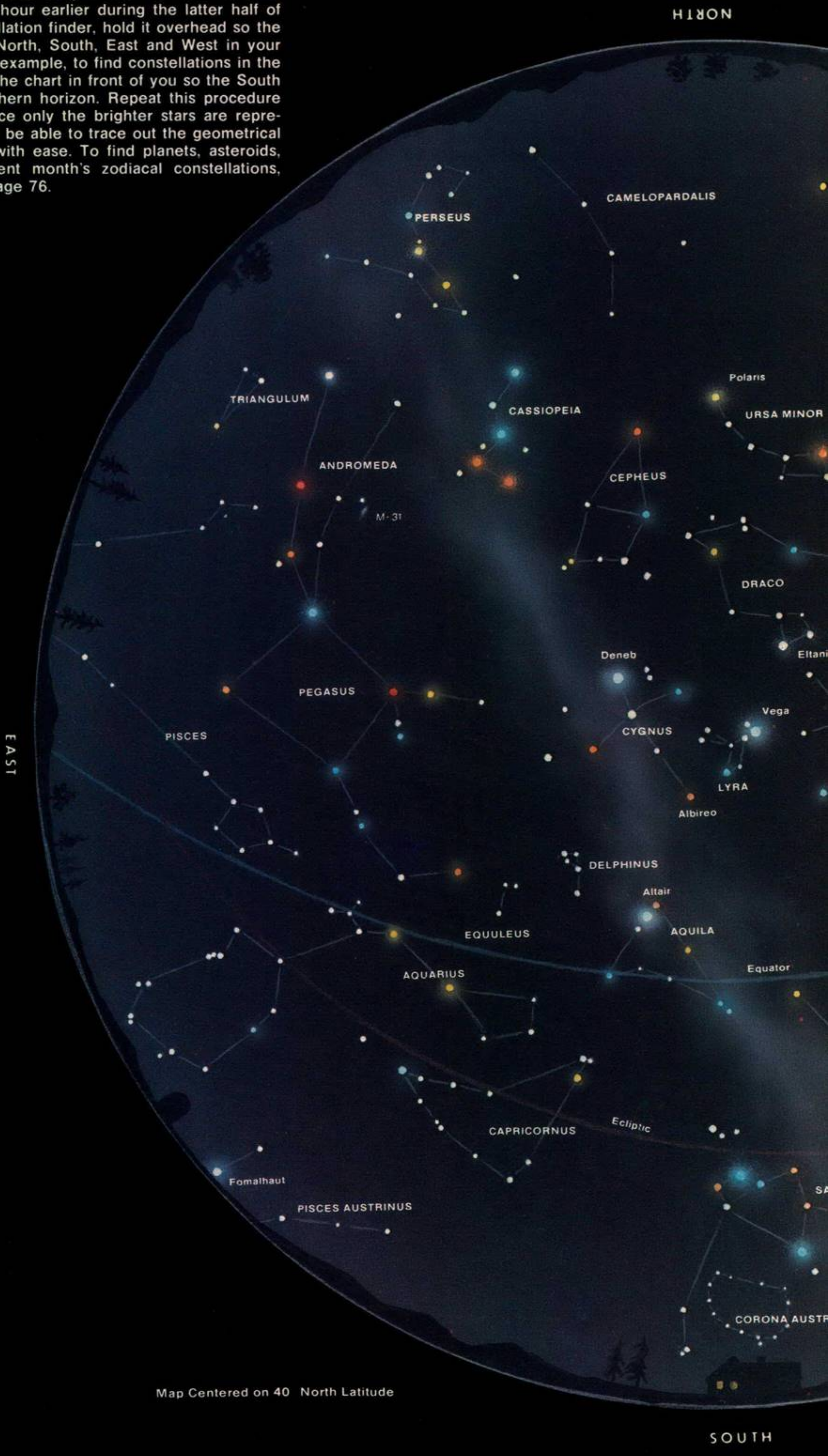
Other nations, however, have or had different ideas about this road. In Sweden, it is Winter St., and the Chinese know it as Yellow Rd. Among English peasantry it was called Watling St., the name of an ancient highway streching from Chester to Dover, while in Celtic countries, the Milky Way was Arianrod or Silver St.

It follows naturally that if the Milky Way is a road, there should be legends concerning its travelers and their destinations. In summer, the Milky Way appears to rise from Earth toward the zenith; thus many stories tell how a road, rising from the edge of the world, leads to heaven. To the Norsemen, the Milky Way was the road that dead heroes followed to Valhalla, home of the gods (although in later times the rainbow assumed this function). American Indians had the same idea, and the brighter stars along the Milky Way were the heroes' campfires. Natives of Patagonia believed their dead friends were hunting ostriches along the way, and the early Hindus called it the path that Ahriman took to his throne in heaven.

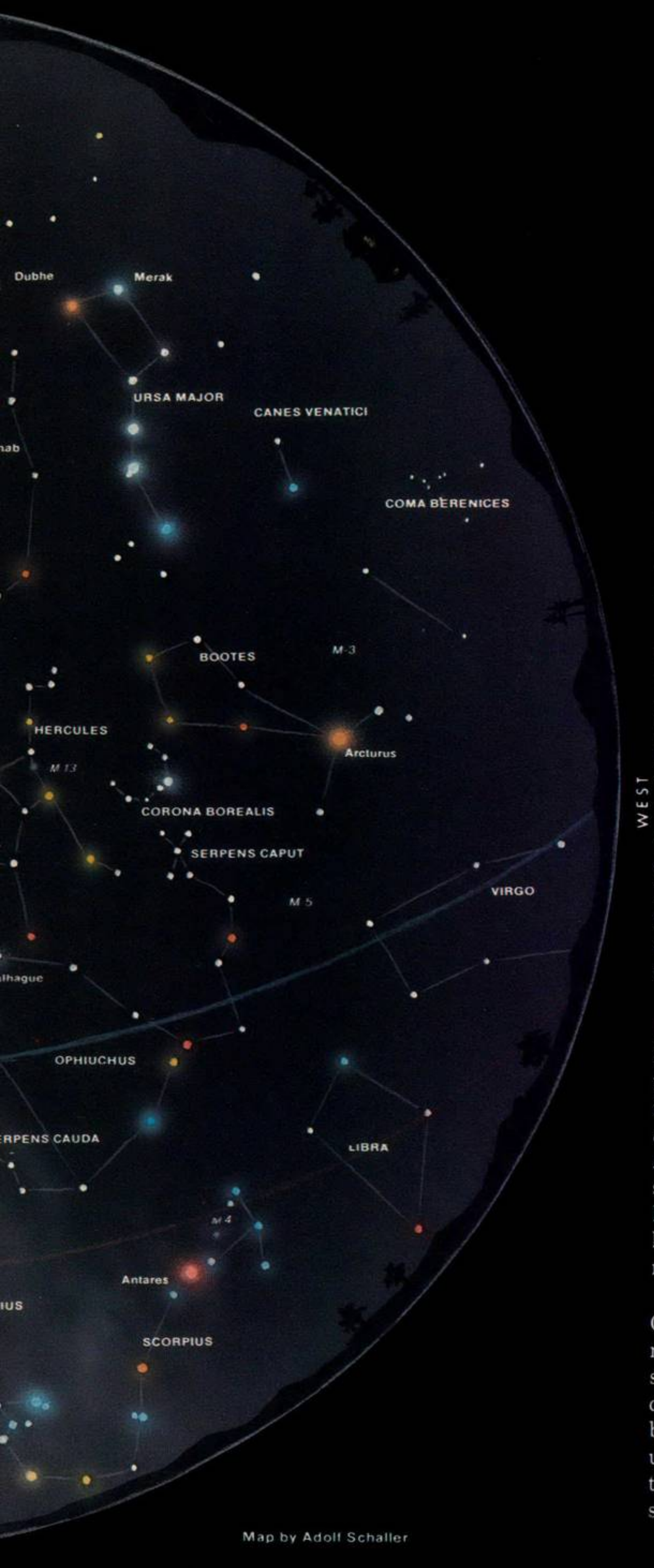
In northern India, the Milky Way is called the path of the snake, providing another example of widely separated peoples having similar sky legends; the Norse told of the Midgard serpent, a monstrous snake that surrounded the world. In some stories the serpent lived in the ocean, but elsewhere the Milky Way is either the home of the snake or the snake itself. The Akkadians also knew the galaxy as the great serpent.

A story from Finland tells of how the lovers Zulamith and Salami, wanting to be united in heaven, built a "starry bridge of light"; after they completed

This Star Dome rendering approximates the sky as it appears at about 11 p.m. Local Daylight Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page 76.


NORTH
PERSEUS
CAMELOPARDALIS
TRIANGULUM
CASSIOPEIA
Polaris
URSA MINOR
ANDROMEDA
M-31
CEPHEUS
DRACO
Deneb
Eltani
PEGASUS
Vega
PISCES
CYGNUS
EAST
LYRA
Albireo
DELPHINUS
Altair
EQUULEUS
AQUILA
Equator
AQUARIUS
Ecliptic
CAPRICORNUS
Fomalhaut
PISCES AUSTRINUS
SA
CORONA AUSTR
SOUTH

Map Centered on 40 North Latitude



Map by Adolf Schaller

the task, they were joined together into the star Sirius. Another Finnish story returns us to the notion of the Milky Way as a river. To the Finns, Tuonela, the land of death, was surrounded by a wide river that has been identified by some as the Milky Way. On this river swam a black swan, singing a melodious, mournful song. In order to win the hand of the daughter of Louhi, ruler of Pohjola, the hero Lemminkäinen was ordered to make his way to Tuonela and shoot the river-swan. The hero's first arrow missed; before he could aim another, a shepherd, determined to prevent the sacrilegious act, attacked Lemminkäinen with his sword and killed the hero. After dismembering the body, the shepherd threw the pieces into the river, which carried them to the land of death.

If the Milky Way is indeed the river surrounding Tuonela, it's easy to see the swan (Cygnus) swimming down it, as well as Lemminkäinen's first arrow (Sagitta) narrowly missing the bird's head.

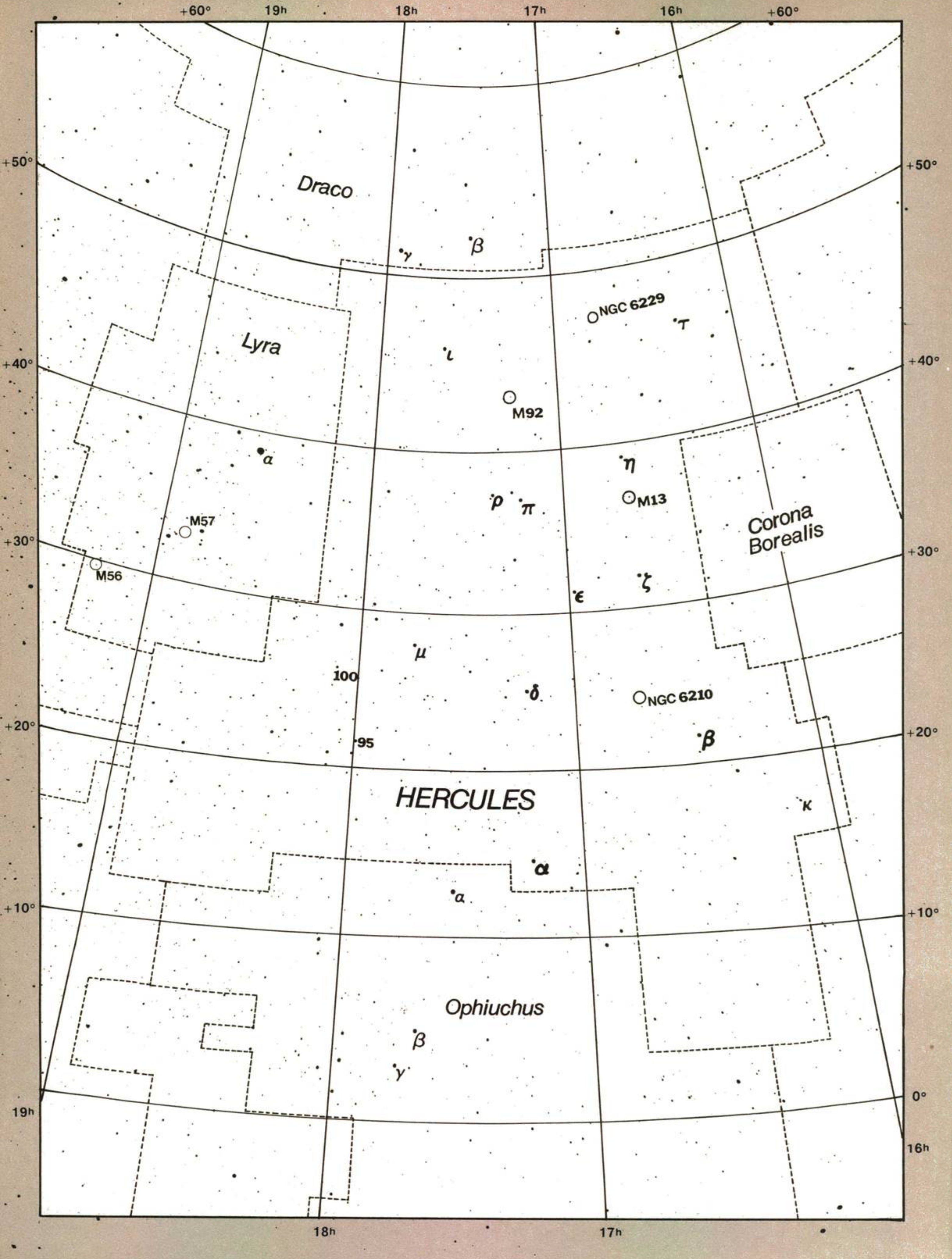
The tale, incidentally, ends happily, for Lemminkäinen's mother wore a ring that turned chill when her son was in danger. Learning in this manner of his death, she was able to restore her son to life and health by magic. The composer Jean Sibelius relates the story in his *Four Legends* for orchestra.

If Cygnus and Sagitta are the swan and the arrow, might Lemminkäinen himself be in the sky? We could choose to see him in the constellation Hercules, in place of that hero. This would actually not be inappropriate, for Hercules has had more identifications in its long history than any other constellation. In fact, the name "Hercules" is a very recent title for this group, which originally had nothing to do with that greatest of Greek heroes. The Greeks themselves did not know the constellation by that name, and it was only during Roman times that Hercules finally found his way into the sky. The Greeks called the group the kneeler — a nameless man, bent on one knee with his other foot on the head of Draco the dragon.

We've previously mentioned (Star Dome, April 1976) that the constellations may originally have been intended to represent the important occupations of the day: hunters, farmers or warriors. If so, Hercules' identification has long been lost, because to the Greeks and early Arabs he was simply the anonymous kneeler. Aratos, in 270 B.C., wrote that "No one can clearly speak of him, nor upon what task he is bent; but simply Kneeler they call him." Also titled the leaper, the keen-eyed one, or the club-wielder in Greek days, the man remained unnamed.

Why should this be so? We have seen that the Greeks were ingenious in devising stories to complement their sky figures; yet here is a group that exists, so to speak, in a void. Today, of course, there are many constellations associated by legend with Hercules, but these are recent additions to skylore. Hercules' upside-down orientation in the sky is yet another addition to the puzzle; no other constellation except Pegasus stands on its head in manner.

But if the Greeks were reluctant to assign a name



+60°
19h
18h
17h
16h
+60°
+50°
+50°
+40°
+40°
+30°
+30°
+20°
+20°
+10°
+10°
0°
19h
16h
18h
17h
Draco
β
γ
NGC 6229
τ
Lyra
ι
M92
α
η
ρ
π
M13
M57
Corona
Borealis
M56
ζ
ϵ
μ
100
δ
NGC 6210
95
β
HERCULES
κ
α
α
Ophiuchus
β
γ

Photograph by Robert Provin and Brad Wallis/Map by Victor Costanzo to the kneeler, other nations certainly were not. There is evidence that the group may have represented the Chaldeans' great hero Gilgamesh. A Chaldean cylinder seal dating from about 3000 B.C. shows Gilgamesh resting on one knee, with the other foot propped on the head of the dragon Tiamat — the exact pose assigned the figure in the sky. The Greeks, in fact, may have adopted the figure of Gilgamesh into their own mythology, transforming him into Hercules in the process.

Later, Hercules was changed by the Arabians into the dancer, although the Arabian word is translated by some as posturer. Still other names for the constellation have been Prometheus, Theseus, Orpheus (fittingly enough, with Lyra the lyre nearby), and Ixion. This last is the name of a figure in Greek legend who, after a crime committed against Zeus, was punished in Hades by being tied to a wheel that revolved forever. The constellation's daily motion around the pole may even have suggested the story of Ixion to its inventors.

Surprisingly, there is no mention anywhere in old records of the famous globular cluster M-13. Its first appearance in any written record is in 1714, when it was first seen by Sir Edmund Halley. Since the cluster is visible to the naked eye on clear nights, it is remarkable that it successfully avoided recognition prior to Halley's discovery.

Still one more mystery is associated with Hercules. The constellation is indistinct; the only easily recognizable pattern is the keystone, made up of third and fourth magnitude stars. Why, then, has the group been so important to so many nations? In old records, it is always one of the most prominent figures in the sky, despite its faintness and anonymity.

The checkered career of Hercules is something to puzzle over while observing it on a clear August night.

Close-Up on the Hercules Region

"Dim but interesting" is an accurate description of Hercules, just past the meridian on August evenings. Although it contains no star brighter than third magnitude, this constellation holds within its boundaries a vast store of celestial bounty for the telescopic hunter. Altogether, Hercules encompasses 1,225 square degrees of the sky, ranking it fifth among the constellations in order of size. The heart of the figure is the well-known keystone, marked by the stars Eta, Zeta, Pi and Epsilon. Lines of stars outlining the arms and legs of the mighty hero radiate from this distinctive grouping.

Barns tells us that Hercules "discloses many rarities in radiant fields to the south and southeast". The constellation contains a seemingly inexhaustible supply of fine double stars, displaying every imaginable combination of magnitudes, separations and colors. Only some of the more attractive ones could be listed in our Table of Selected Objects. Indeed, it is somewhat of a mystery why this area of sky should harbor so many fine pairs while other regions are almost devoid of them.

Hercules also is the home of several fine globular star clusters, as detailed in Eyepiece Impressions. One of these — M-13, the famed Hercules cluster — is the finest representative of its class in the northern sky. Located 1/3 of the way from Eta to Zeta in the keystone, M-13 glows at magnitude 5.7 and can be glimpsed with the unaided eye on a dark transparent night. Binoculars clearly reveal its fuzzy, nonstellar appearance. Halley, who discovered it in 1716, referred to it as "a little patch".

Another naked eye feature of this constellation is the star Alpha, known as Ras Algethi (the kneeler's head) and located south of the keystone. This reddish-orange giant of spectral class M is a semiregular variable, slumbering fitfully between third and fourth magnitudes with no certain period. A good reference star to use in checking on Alpha's variations is Delta Herculis, 10 degrees due north and shining at a constant 3.2 magnitude. The two stars nearly match in brightness on some nights, while on others Alpha is noticeably fainter.

Eyepiece Impressions

Zeta (ζ) Herculis

We begin our telescopic survey of Hercules with a selection of four distinctly different double stars. The first of these is Zeta, marking the lower right corner of the keystone.

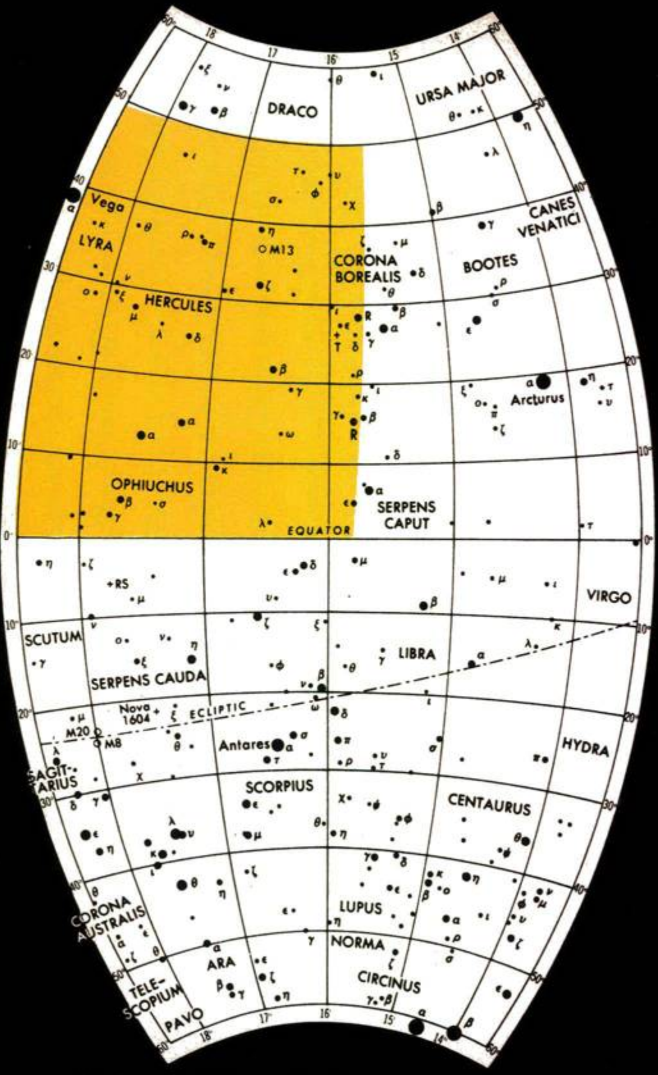
This binary star consists of 3.1 and 5.6 magnitude components, presently a tight 1.2 seconds of arc apart. With a period of just 34 years, this pair has completed more than five revolutions since its discovery by Sir William Herschel in 1782. As a result, Zeta's orbit is one of the best determined in the sky. At closest approach (as in March 1967), the stars' separation drops to just under 0.5 seconds. The double is now opening fairly rapidly and will reach a maximum of 1.6 seconds in November 1990.

At least a six inch telescope is needed to clearly split the pair now, although tantalizing glimpses of elongation can be had even in a three inch refractor at 150 to 200 power in good seeing. The components are yellow and red, and even when the stars are unresolved, their blended hues can be seen at high magnifications.

Try separating this tightly bound duo with your telescope the next clear tranquil night. Even if you should fail now, keep watching Zeta from season to season as the stars move apart. Some night, when least expected, the pair will reach your resolution threshold and suddenly reveal itself.

Delta (δ) Herculis

Our second offering presents an interesting test of magnitude and color, rather than of resolution. This is Delta Herculis, southeast of the keystone and



Map from **Guideposts to the Stars**; reprinted permission of MacMillan Publishing Co.,©1972 by Leslie C. Peltier.

Stars in each constellation are indicated, in order of brightness, with the Greek Alphabet.

α	**Alpha**	η	**Eta**	ν	**Nu**	τ	**Tau**
β	**Beta**	θ	**Theta**	ξ	**Xi**	υ	**Upsilon**
γ	**Gamma**	ι	**Iota**	ο	**Omicron**	φ	**Phi**
δ	**Delta**	κ	**Kappa**	π	**Pi**	χ	**Chi**
ϵ	**Epsilon**	λ	**Lambda**	ρ	**Rho**	ψ	**Psi**
ζ	**Zeta**	μ	**Mu**	σ	**Sigma**	ω	**Omega**

Table of Selected Objects — Hercules Region

Object	Type	Mag.	Size/ Sep.	R.A. (1950)	Dec.
HERCULES					
κ(Kappa)	★2	5.3,6.5	29"	$16^{h}06^{m}$	+17°11'
* ζ(Zeta)	★2	3.1,5.6	1.2"	$16^{h}39^{m}$	+31°42'
* M-13	GC	5.7	10'	$16^{h}40^{m}$	+36°33'
* NGC-6210	PN	9.7	20"x13"	$16^{h}42^{m}$	+23°53'
* NGC-6229	GC	8.7	72"	$16^{h}46^{m}$	+47°37'
*α(Alpha)	★2,V:irr	3.0-4.0,5.4	5"	$17^{h}12^{m}$	+14°27'
* δ(Delta)	★2	3.2,8.8	10"	$17^{h}13^{m}$	+24°54'
* M-92	GC	6.1	8'	$17^{h}16^{m}$	+43°12'
ρ(Rho)	★2	4.5,5.5	4"	$17^{h}22^{m}$	+37°11'
* 95	★2	5.1,5.2	6"	$17^{h}59^{m}$	+21°36'
100	★2	5.9,6.0	14"	$18^{h}06^{m}$	+26°06'

* Detailed in Eyepiece Impressions

★2 = Double Star
GC = Globular Cluster
PN = Planetary Nebula
V:irr = Variable Star, irregular
Mag.= Magnitude
Sep.= Separation

consisting of a 3.2 magnitude primary attended by an 8.8 magnitude companion about 10 seconds away.

Delta is an example of an unusual class of objects known as *optical* doubles (two unrelated stars at different distances from us). The "companion" happens to lie in the same line of sight but is actually much more distant than the primary, a mere 100 light-years away. The gap between them is closing as the two stars appear to cross paths with each other, making Delta look more than ever like a real (gravitationally coupled) double star.

The faint star can be glimpsed in a 2.4 inch refractor at 35 power or more on a good night. At least a four inch at 90 power, however, is needed to detect this object's color. With larger aperture, Delta becomes increasingly lovely as a magnitude contrast pair.

Barns called this double "a study in color" — and rightly so, for countless hues have been reported. Most observers see the pair as cream and lilac; but green and purple, pale yellow and bluish-green, green and ashy white, yellow-white and azure, and even greenish-white and grape red have been recorded! The actual spectral types of the stars are A0 and G2. What colors do you find for this "fake" but interesting duo?

Alpha (α) Herculis

Those seeking a spectacular double to show visitors at the telescope are sure to be pleased with third magnitude (sometimes fourth) Alpha Herculis. Located south of the keystone, it is not far from second magnitude Alpha Ophiuchi.

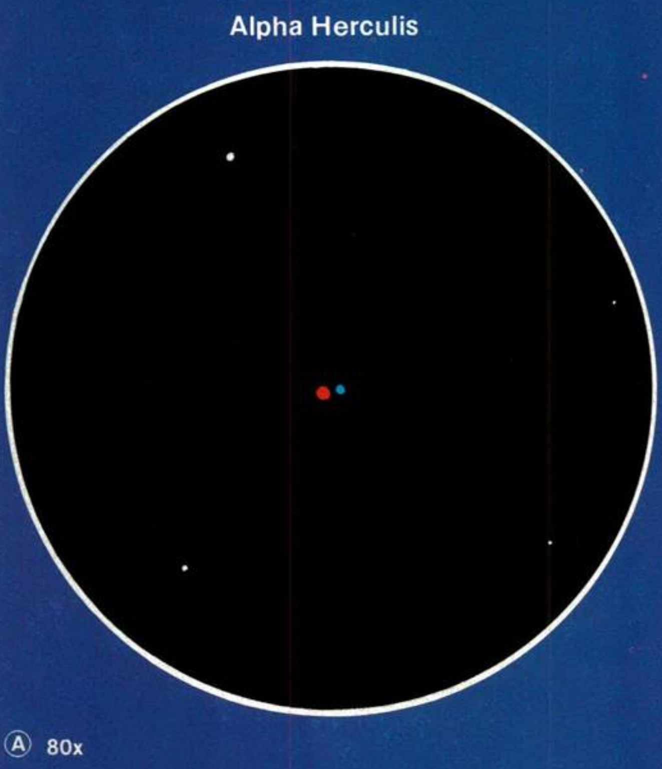
Alpha Herculis consists of a stunning combination of third magnitude orange and fifth magnitude blue-green suns, a comfortable 4.6 seconds apart. Unlike Delta, Alpha's tints are strong and easy to see without guessing. A 2.4 inch refractor at 100 power nicely resolves Alpha, while three and four inch scopes give the kind of view shown in our drawing. Larger telescopes simply add to an already beautiful scene.

Smyth called this pair "a lovely object, one of the finest in the heavens". Webb gives the primary as very yellow or orange, and the companion as blue, bluish-green, or emerald on different occasions. Olcott simply states "orange and green" while Barns strangely makes no comment on the colors. The spectral types are M5 for the primary and G for the companion.

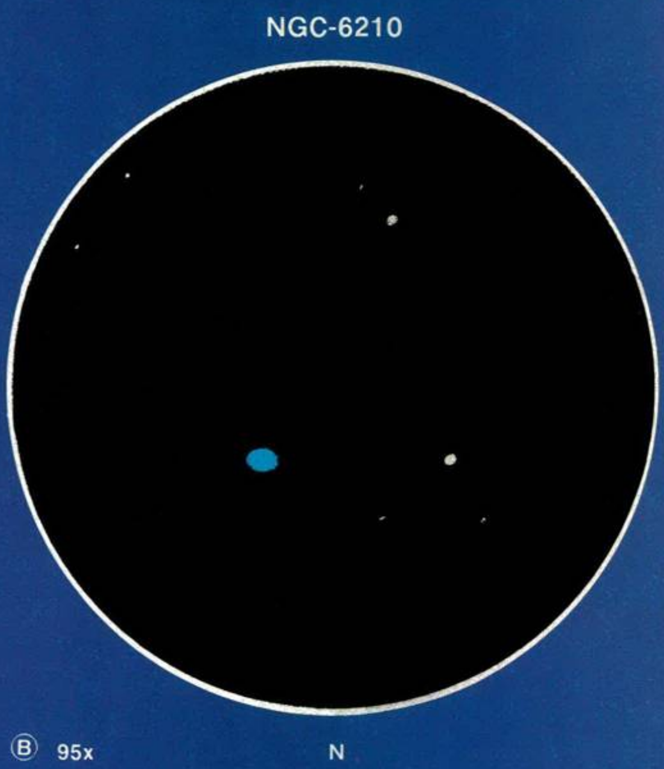
This stellar couple lies 540 light-years from us; the stars are apparently in very slow orbital motion about each other. The primary is a pulsating giant star, whose tenuous outer atmosphere has been found to actually engulf the companion sun. This small star is known to be a spectroscopic binary with a period of 52 days, making Alpha at least a triple system. Quite a varied and beautiful spectacle must grace the sky of any planet there.

95 Herculis

Our fourth pair provides one of the subtlest, yet most beautiful, combinations of celestial color any-


Alpha Herculis

Ⓐ 80x


NGC-6210

Ⓑ 95x

Hercules abounds in double star systems, and one of the finest is Alpha Herculis, seen in diagram A through a 3.5 inch Questar catadioptric at 80 power. The brighter star is a red giant variable, while the companion is vivid green. The field of view here is about 35 minutes of arc. Diagram B shows the planetary nebula NGC-6210 — a challenge to locate, but well worth the effort. A four inch Schmidt reflector at 95 power reveals the blue-green ovoid; the 30 minute-of-arc field of view shows it as one of a triangle of stars. Even the smallest telescopes will provide a glorious view of the spectacular globular cluster M-13, as diagram C attests; a 2.4 inch Unitron refractor at 38 power can resolve the cluster almost to its core. This swarming ball of suns sits in the center of a field of view of 75 minutes of arc. Drawings by James Mullaney.

where in the sky. Found by drawing a line from Epsilon (ϵ) to Lambda (λ) and extending it its own length, the double 95 Herculis is one of a group of naked eye stars in eastern Hercules.

The components of 95 are nearly matched fifth magnitude suns, 6.5 seconds apart. A 2.4 inch refractor at 35 power splits them nicely; 75 to 100 power makes the color contrast apparent. Larger instruments enhance the tints greatly.

The finest color notation for this pair is that given long ago by Smyth: "apple green and cherry red" — and so they look to most eyes. Other less charming terms such as pale (or yellow) red and pale (or yellowish) green have been recorded, amounting to the same thing. Not to be outdone, Barns christened the duo as "beryl and sardonyx"! These tints are delicate but persistent in all apertures.

Webb agreed with Smyth's colors and added that 95 Herculis is "extremely pretty". He also called attention to the strange discrepancies in color reported among early observers, when comments such as "red the larger, green the brighter" were made. We should try to confirm such descriptions by actual observation at the telescope.

NGC-6210

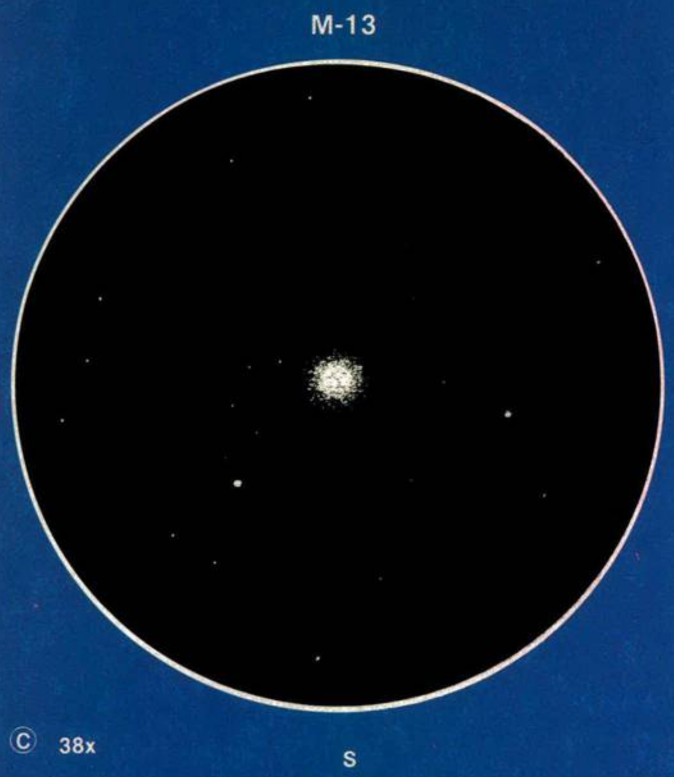
For a change of pace, we next offer a little planetary nebula. Like most of its kind, location of NGC-6210 presents a test of observing skill. Lying slightly more than one degree southwest of fifth magnitude 51 Herculis, a line from Gamma (γ) to Beta (β) also points to its neighborhood. Sweeping with a low power, wide field eyepiece will reveal a triangle of stars — one of which is actually the nebula.

NGC-6210 appears as an eerie, 9.7 magnitude blue-green egg, 20 by 13 seconds of arc in size. (Some observers make it as small as eight seconds.) It's fun to see how low a magnification will distinguish the planetary from a star; 45 power on a three inch refractor will do for a trained eye in this case. A definite disk can be made out at about 75 power on three and four inch scopes. A six inch reflector at 100 power gives a fine view, while eight inch and larger instruments at 150 power or more make this a real showpiece.

NGC-6210 is one of a handful of small nebulae picked up by F.G.W. Struve during his double star searches. This planetary is one of the few notable objects overlooked by Herschel in his great sweeps of the heavens. Many observers have likened this "cosmic pea" to a star out of focus. Some owners of large reflectors report its disk as an intense blue in color, but most see green with only a tinge of blue as shown in our drawing. Large apertures at high magnification will also reveal a faint outer halo surrounding the bright disk itself.

NGC-6229

We complete our survey of Hercules with three globular star clusters. The first of these is the "misidentified" object known as NGC-6229, situated midway between two fifth magnitude stars — 42 and 52



Herculis. A line from Zeta through Eta (η) in the keystone points directly at the latter star.

This 8.7 magnitude globular is only about 72 seconds of arc in diameter; upon its discovery by Herschel, it was mistaken for a planetary nebula. For many years thereafter observers believed they were viewing the disk of a planetary rather than a compact ball of stars. Webb, for example, describes NGC-6229 as a "Planetary nebula, faint with 3.7 inch (refractor), but beautifully grouped in a triangle with two 6th magnitude stars." Barns was also deceived despite his 10 inch reflector: "Sea-green in starry triangle."

A 2.4 inch refractor at 35 power shows this object on a dark night while a four inch reflector at 45 power or more reveals it as a fuzzy globe of light. Being grouped in a triangle makes it more attractive than it might be by itself. Now that you know its true nature, what does it resemble in your scope — a cluster or a nebula?

M-92

One of the brightest globular clusters in the sky can be found north of the keystone, forming the top of a triangle with Pi (π) and Eta Herculis. This is M-92, located roughly midway between Eta and Iota (ι). Low power sweeping will readily pick it up despite the absence of any nearby guide stars.

Glowing at magnitude 6.1 and having an angular diameter of more than eight minutes, M-92 is a fine sight in the smallest of instruments. The edge of the globe can be resolved into points of light with a three inch refractor at 90 power, and a four inch reflector at 95 power will almost resolve the dense core.

Webb called M-92 "A very fine cluster, though not equal to M-13; less resolvable, intensely bright in center." Buffham, one of Webb's fellow observers, commented: "Stars brighter and more compressed than M-13, but blaze resolved by glimpses." Most observers today would agree with these descriptive comparisons.

Although undoubtedly overshadowed by its famous neighbor M-13, this glittering beehive of stars can easily keep you at the eyepiece half the night with its entrancing beauty.

M-13

We end this month's explorations with one of nature's grandest sights: the great globular star cluster M-13, easily found a third of the way from Eta to Zeta in the keystone of Hercules.

This colossal globe of scintillating suns shines with an integrated magnitude of 5.7 (near the naked eye limit), and occupies an area at least 10 minutes of arc in extent. Best known of all globulars, it is also the finest example of its class in the northern sky.

Even a 2.4 inch refractor at low power gives a striking view, as shown in our drawing. At 100 power, such an instrument can resolve clumps of stars right into the center of the cluster! As telescope size increases beyond six inches, we are at a loss to describe the scene before us. Larger instruments provide a truly stunning visual experience, and we can only guess at the impact of viewing M-13 in observatory telescopes.

For maximum effect, seek dark transparent nights having at least fairly good seeing; use averted vision and simply allow the cluster to drift entirely across the field.

Webb called M-13 a "superb globular cluster", and told us that Messier was sure it contained no stars (bespeaking the poor quality of Messier's telescopes). Smyth added "an extensive and magnificent mass of stars", while Sir John Herschel called attention to "hairy-looking curvilinear branches". These curving star chains are well seen in large apertures.

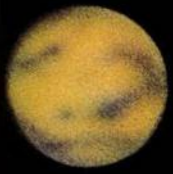
Perhaps the best classic description of M-13 was made by Barns: "In a small glass a curious olivine blurr, often resolvable; but viewed with apertures of increased light-gathering power, a blazing panoply of suns of varied tints and staggering brilliancy."

This great cluster is about 25,000 light-years from us and at least 100 light-years in diameter. From actual star counts at the telescope, Herschel estimated it contained at least 14,000 individual stars. Photographs show perhaps 100,000 — and these are only the brighter members; stars like our sun would be beyond reach of the largest existing telescopes at that distance!

Other features of interest to the advanced visual observer are three dark rifts or lanes near the center of the cluster, often reported but never really confirmed, and a 12th magnitude galaxy (NGC-6207) less than one degree north-northeast of the nucleus.

Whether novice or veteran stargazer, gaze at this incredible profusion of supersuns long and hard. Drift after drift, let its eons-old light saturate your eye and imagination. Then you may feel, as did Emerson, that "The calm, remote and secular character of astronomical facts composes us to a sublime peace."

Planet Finder



Ⓒ **Ceres**

Aug.	1	15
R.A.	8h38m	9h05m
Dec.	+23°58'	+22°36'
Mag.	+8.8	+8.8

Ⓐ **Mercury**

Aug.	1
R.A.	9h59m
Dec.	+14°20'
Mag.	-0.5

Ⓑ **Mercury**

Aug.	15
R.A.	11h16m
Dec.	+4°03'
Mag.	+0.2

Ⓜ **Mars**

Aug.	1	15
R.A.	11h09m	11h41m
Dec.	+6°20'	+2°45'
Mag.	+1.9	+1.9

Ⓝ **Neptune**

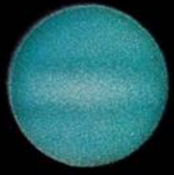
Aug.	15
R.A.	16h39m
Dec.	-20°36'
Mag.	+7.7

SUN

The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

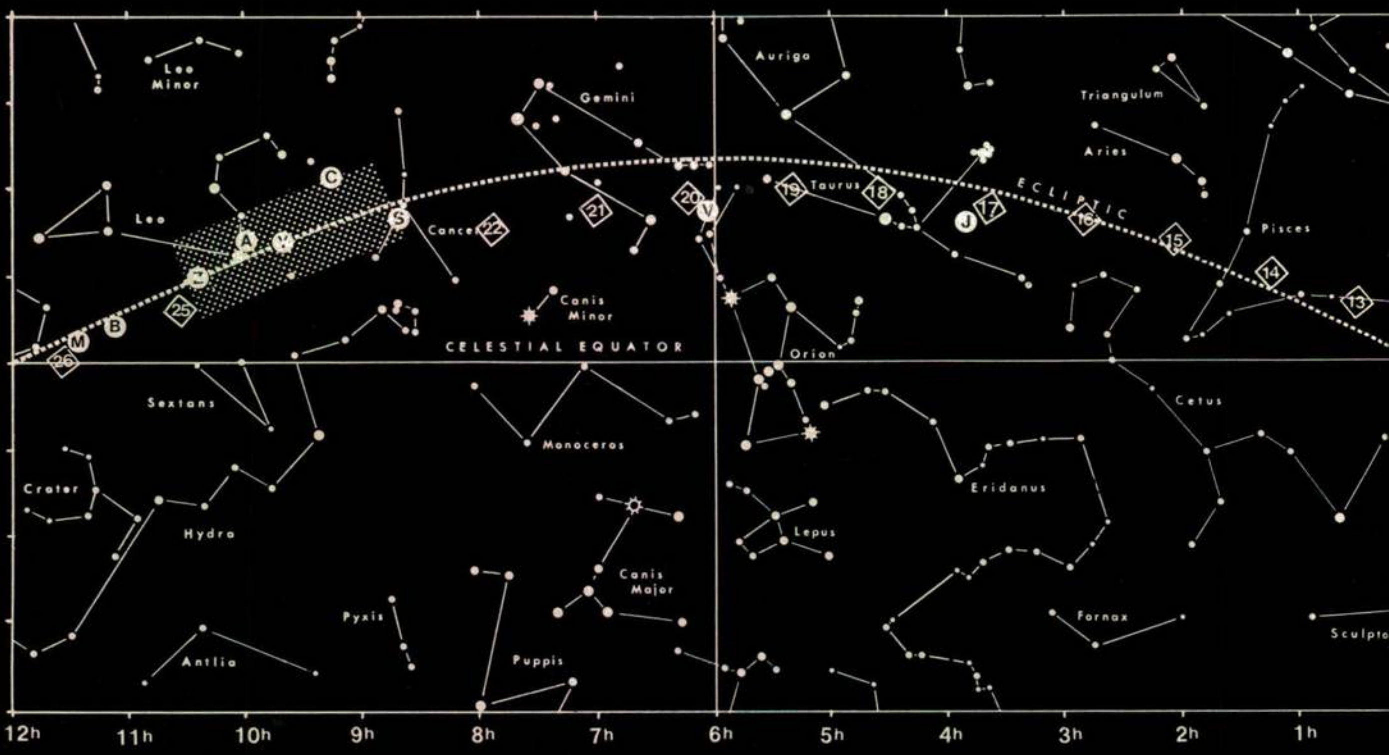
Ⓢ **Saturn**

Aug.	1	15
R.A.	8h38m	8h45m
Dec.	+19°01'	+18°34'
Mag.	+0.4	+0.5



Ⓤ **Uranus**

Aug.	15
R.A.	14h06m
Dec.	-12°16'
Mag.	+5.7

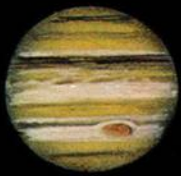

Leo Minor
Auriga
Gemini
Triangulum
Aries
Leo
C
S
A
Cancer
22
21
20
V
19
Taurus
18
J
17
ECLIPTIC
16
15
Pisces
14
13
25
M
B
26
Canis Minor
CELESTIAL EQUATOR
Orion
Sextans
Monoceros
Cetus
Crater
Hydra
Eridanus
Lepus
Canis Major
Pyxis
Fornax
Sculpto
Antlia
Puppis
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h

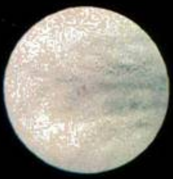
The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec . = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag . = magnitude, a

August 1976

Ⓥ **Vesta**

Aug.	1	15
R.A.	5h47m	6h10m
Dec.	+20°24'	+20°34'
Mag.	+8.8	+8.8





Ⓙ **Jupiter**

Aug.	1	15
R.A.	3h42m	3h49m
Dec.	+18°37'	+18°59'
Mag.	-1.9	-2.0

Ⓨ **Venus**

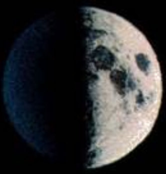
Aug.	1
R.A.	9h40m
Dec.	+15°29'
Mag.	-3.4

Ⓩ **Venus**

Aug.	15
R.A.	10h46m
Dec.	+9°22'
Mag.	-3.3

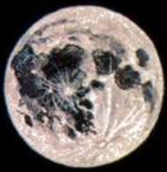
Ⓟ **Pluto**

Aug.	15
R.A.	13h00m
Dec.	+11°29'
Mag.	+14



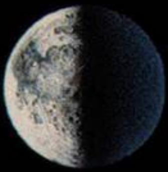
First Quarter

August 2
August 31



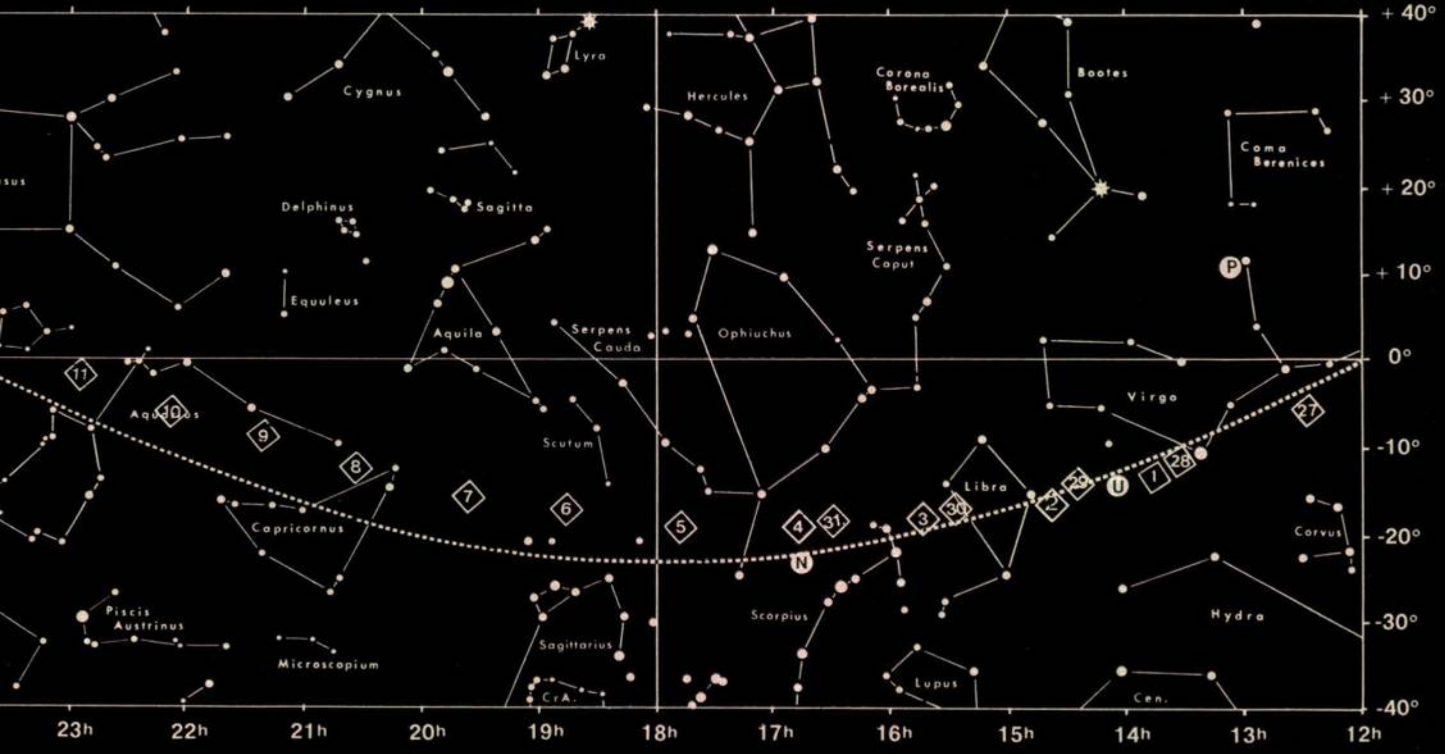
Full Moon

August 9



Last Quarter

August 17



Lyra
Cygnus
Hercules
Corona Borealis
Bootes
Coma Berenices
sus
Delphinus
Sagitta
Serpens Caput
Equuleus
Aquila
Serpens Cauda
Ophiuchus
Virgo
Aquarius
Scutum
Libra
Capricornus
Corvus
Scorpius
Piscis Austrinus
Microscopium
Sagittarius
Hydra
Lupus
CrA.
Cen.
P
N
U
1
2
3
4
5
6
7
8
9
10
11
27
28
29
30
31
+40°
+30°
+20°
+10°
0°
-10°
-20°
-30°
-40°
23h
22h
21h
20h
19h
18h
17h
16h
15h
14h
13h
12h

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.

History of American Astronomy

July 1976 Special Bicentennial Issue From ASTRONOMY

The July 1976 issue of ASTRONOMY is entirely devoted to the history of astronomy in the United States. While focusing on the two centuries of America's history as a nation—from the signing of the Declaration of Independence through today—this unique issue also explores the astronomy practiced by, and skylore of, indigenous Americans who greeted the earliest colonists.

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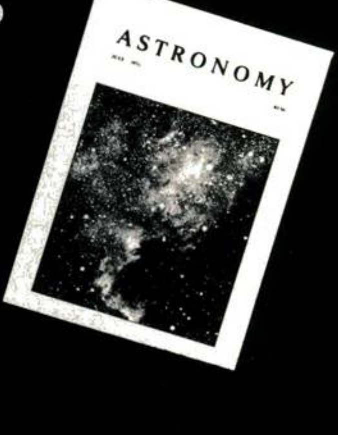

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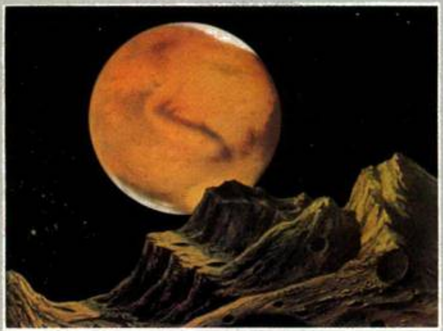
From ASTRONOMY

Mars as Seen From Deimos



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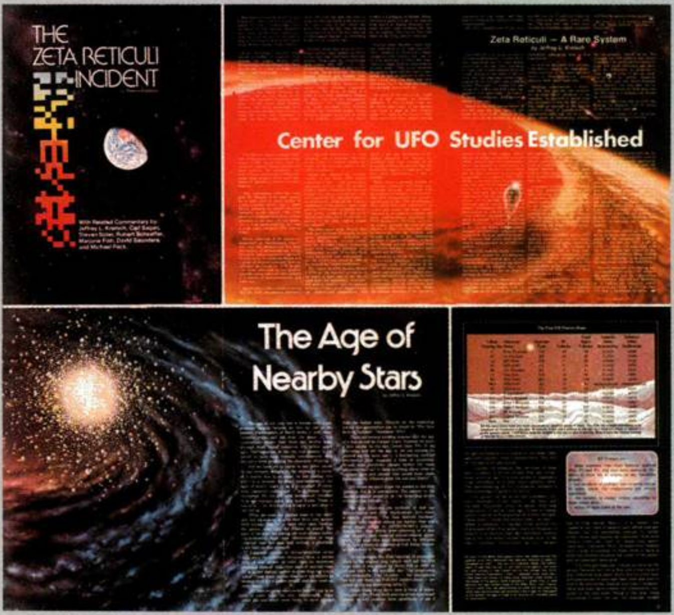
Painted by Victor Costanzo, this authentic, artistic rendition is set against a real star background as though Mars were in the constellation Taurus. Full color, varnished, suitable for framing. All posters listed here are insured and mailed in a heavy duty mailing tube.


THE ZETA RETICULI INCIDENT
Zeta Reticuli — A Rare System
Center for UFO Studies Established
The Age of Nearby Stars

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This exciting reprint combines, in one 32 page source, articles and commentary that appeared in ASTRONOMY which documented the astronomical implications of an alleged star map seen aboard a UFO by Betty and Barney Hill. While not offering incontrovertable proof that alien visitors to Earth live on a planet circling the star Zeta Reticuli, the astronomical detective work is persuasive. Commentary is provided by scientist Carl Sagan and Steven Soter as well as Jeffrey Kretsch, Robert Scheaffer, Marjorie Fish, David Saunders and Michael Peck. Full color, illustrated throughout, varnished cover.

Milky Way in. Sagittarius

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Photograph made by Orien A. Ernest using a home built cold camera shows clusters, nebulae and star clouds in true relationship to each other and to the constellation Sagittarius' teapot asterism. Better than a star atlas of this sky region, the photograph reveals in dramatic reds, golds and blues, objects you can easily find with your naked eye or binoculars. Varnished, suitable for framing, mailed in a heavy duty mailing tube, insured.

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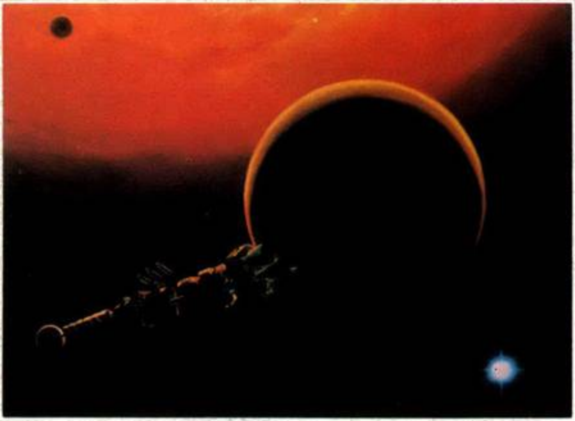
Exploration of Antares Star System



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Painted by John Clark, this imaginative rendition shows a 21st century starship exploring a scorched Earth sized planet and its moon in orbit about Antares. The red super giant star looms ominously, filling most of the sky while Antares' blue-white dwarf star companion is seen at lower right. Full color varnished, framable.

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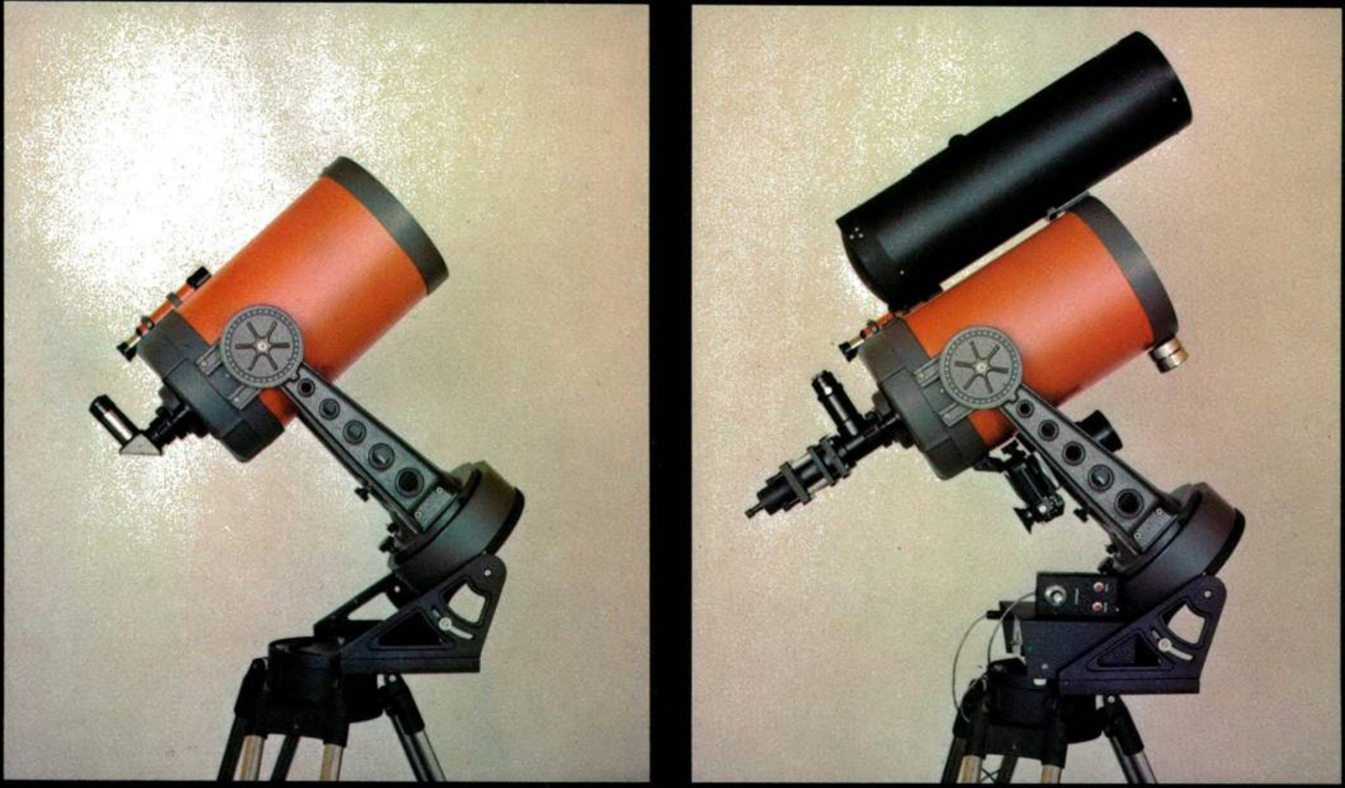

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LEFT: The basic Celestron 8, with setting circles and electric clock drive ($790), mounted on equatorial wedge and tripod for observations in the field. The simplicity of this system has helped make the Celestron 8 the world's best-selling compact-portable telescope. RIGHT: The Celestron 8, as it might be set up for multiple-field deep-sky photography, with a telephoto lens and a Celestron Schmidt Camera mounted piggyback, and a 35mm cold camera mounted at first focus behind the Celestron off-axis guiding assembly.